CARPENTRY
IN
NEW ZEALAND

CARPENTRY

IN

NEW ZEALAND

This book was written and prepared
for publication by
THE NEW ZEALAND TECHNICAL CORRESPONDENCE INSTITUTE
DEPARTMENT OF EDUCATION

1969
A. R. SHEARER, GOVERNMENT PRINTER, WELLINGTON
NEW ZEALAND

First printed 1958
Second Edition 1960
Third Edition 1963
Fourth Edition 1966
Fifth Edition 1969

PRINTED BY WHITCOMBE AND TOMBS LTD., WELLINGTON, UNDER AUTHORITY,
A. R. SHEARER, GOVERNMENT PRINTER, WELLINGTON, NEW ZEALAND, 1969

FOREWORD

I welcome most heartily the publication of this book on Carpentry for New Zealand readers.

The early settlers of this country, carrying with them the traditions of their native land, found that they had to recast their ideas in a great many ways. Perhaps no more radical change had to be made than in the building of their dwellings.

As the years passed New Zealand evolved a system of house building, profoundly influenced by climate, building materials, and economic and social considerations, that has no exact counterpart in any other country.

This textbook, designed primarily for the use of apprentices attending vocational classes in our Technical Colleges, provides an authoritative guide to New Zealand practice in carpentry. It will appeal, I am sure, to a much wider public, including that sturdy, independent, do-it-yourself householder, so commonly met in this country.

I should like to take this opportunity of extending my thanks to the various organisations connected with the building trade who have assisted so generously in the preparation of the text of this book. I feel confident that, as a result, it makes a valuable contribution to technical education in New Zealand.

Minister of Education

PREFACE

Carpentry in New Zealand, prepared by the New Zealand Technical Correspondence Institute of the Department of Education uses as a basis material that for a number of years has been issued in the form of lessons to apprentices preparing for examinations in carpentry conducted by the New Zealand Trades Certification Board.

To plan the production of the book, an advisory committee was set up consisting of representatives of the Department of Education, the Master Builders' Federation, the New Zealand Carpenters' and Joiners' Union, the Post-Primary Teachers' Association, and the Commissioner of Apprenticeship. This committee later acted in an editorial capacity, and, by widely circulating cyclostyled chapters of the book as they were prepared, ensured that interested people in every part of New Zealand were given an opportunity to comment and advise. The help given by the members of this committee is gratefully acknowledged.

Thanks are due also to the Standards Institute and the New Zealand Portland Cement Association for information and suggestions, the Ministry of Works Housing Division for the use of plans, the Forest Service and the Entomological Research Station for the loan of drawings and photographs, the National Publicity Studios for the photographing of tools kindly lent for the purpose by J. C. Riddell & Co. Ltd., Briscoe, E. W. Mills & Co. Ltd., and John Duthie & Co. Ltd., Wellington, and the New Zealand Master Builders' Federation for assistance with typing.

CONTENTS

Chapter		*Page*
1	CARPENTERS' TOOLS	11
2	BUILDING PRELIMINARIES—PLANS AND PERMITS	38
3	TIMBER	46
4	FOUNDATIONS	75
5	FLOOR FRAMING	90
6	WALL FRAMING	99
7	ROOFING—ROOFS AND ROOF FRAMING	111
8	EXTERIOR WALL COVERINGS	150
9	FLOORING	166
10	FIXING JOINERY	172
11	INTERIOR WALL COVERING	187
12	EXTERIOR AND INTERIOR FINISHING	191
13	ATTENDANCE ON OTHER TRADES	209
14	SCAFFOLDING	212
15	FORMWORK FOR CONCRETE	218
16	CONCRETE	229
INDEX		239

Chapter 1

CARPENTERS' TOOLS

Introduction

In carpentry many hand skills and operations have been replaced by quick and accurate methods through the introduction of portable power tools and machines. Nevertheless, it is still necessary for the apprentice to obtain a set of hand tools and to learn how to use them. The importance of this is recognised in the New Zealand Apprenticeship Order which specifies the tools that an apprentice should have at various stages in his apprenticeship. Before making a purchase, he should seek the advice of a skilled craftsman and tools of the best quality only should be bought.

The application of the knowledge that an apprentice acquires and the skilful use of his tools makes the craftsman. He requires a thorough understanding of the hand tools used in carpentry, and the mechanical principles underlying their design and construction; he must know how to maintain them in first-class condition, how to care for them, and how to use them properly.

Classification of Tools

For convenience, hand tools used by the carpenter may be classified into four groups according to their particular use:

(1) Geometrical tools — those used in setting out, marking, measuring, or testing.

(2) Cutting tools — those used to reduce timber to the required sizes and shapes.

(3) Impelling tools — those used to strike or drive.

(4) Holding and supporting tools — those used to hold and support.

Group 1: Geometrical tools

(a) Marking Tools

Carpenter's pencil.
Marking crayon
Wing compasses
Ordinary lead pencil
Scriber or marking knife
Chalk line — made with fishing line and block of chalk

(b) Measuring Tools

Carpenter's four-fold 3 ft. rule
Steel tapes
Cutting gauge
Marking gauge
Combination marking and mortise gauge
Mortise gauge
Butt gauge

(c) Guiding and Testing Tools

Try square
Combined try and mitre square
Combination square
Steel framing square
Adjustable bevel
Spirit level
Plumb bob
Straight-edge

Group 2: Cutting tools

(a) Paring and Shaving Tools

Planes

German jack plane
Jack plane
Smoothing plane
Trying or jointer plane
Block plane
Spokeshaves
Combination or special-purpose planes for rebates, mouldings, etc.
Rebate plane

Chisels

Firmer chisel
Bevelled-edge firmer chisel
Registered firmer chisel
Gouges
Paring chisel
Butt chisel
Mortise chisel
Rough-facing tool — hatchet

(b) Sawing Tools

Hand saws for straight sawing

Hand or cross-cut saw
Panel saw
Rip saw
Tenon saw

Curve-cutting saws

Compass saw
Nest of saws
Keyhole or pad saw
Coping saw

(c) Abrading and Scraping Tools

Grinding wheels

Grindstones
Composition wheels

Oilstones

Natural oilstones
Artificial oilstones
Oilstone slips

Other abrading and scraping tools

Scraper
Abrasive papers
Files
Rasp

(d) Boring Tools

Bits

Twist bit
Centre bit
Expanding bit
Countersink bit
Wood drills

Group 3: Percussion and impelling tools

Claw hammer
Mallet
Nail punch
Screwdriver
Hand brace
Hand drill
Automatic push drill
Screwdriver bit

Group 4: Holding and supporting tools

Carpenter's bench and appliances
"G" cramps
Pliers
Spanners and wrenches
Pincers
Quick-release cramp
Bar cramp
Bench vice
Saw grips

DESCRIPTION AND USES OF CARPENTERS' TOOLS

A full description of all the features of the various types of tools is beyond the scope of this book; so only the basic principles of design and the proper use of the main tools will be given.

Group 1: Geometrical tools

(a) Marking tools
(*Fig.* 1)

Carpenters' Pencil

The carpenter's pencil has a rectangular-shaped lead, graded hard, medium, and soft.

Marking crayon

A crayon is used to show clearly the position and placing of work, dates of concrete pourings, etc. Crayon markings are resistant to moisture and remain legible for a long time.

Scriber or marking knife

The point of the scriber or marking kinfe is used for pricking off measurements, while the cutting edge is used for marking shoulder and length lines. Such a line severs the fibres on the surface of the wood and so enables a clean and accurate cut to be produced with saw or chisel.

Wing compasses

Wing compasses consist of a pair of adjustable, pointed steel legs hinged at the top and adjusted by means of a thumb screw. They are used: (1) to step off a measurement several times: (2) to scribe a line to match an irregular surface, e.g., in fitting skirting, weatherboards, or scribers; (3) to mark circles or arcs.

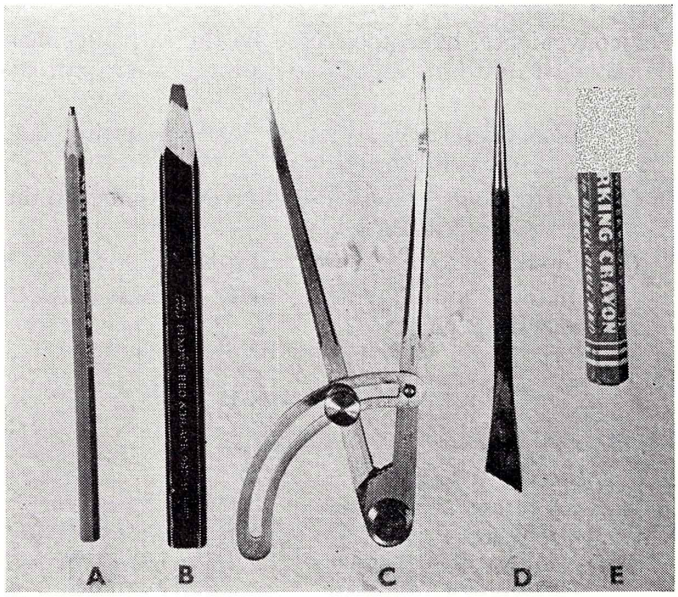


Fig. 1

Marking tools

(A) *Ordinary lead pencil*
(B) *Carpenter's pencil*
(C) *Wing compasses*
(D) *Scriber or marking knife*
(E) *Marking crayon*

Chalk line

The chalk line has a number of uses. If a straight line is required on a horizontal surface, e.g., a floor, the line is first chalked and then stretched taut between two points. About midway, the line is raised vertically and allowed to snap back on to the floor leaving a clear straight line. The chalk line may also be used on vertical surfaces.

(b) Measuring tools

Carpenter's rule (*Fig.* 2)

The rule most favoured by carpenters is the wide-type, four-fold 3 ft. boxwood rule. It is graduated in inches, eighths, tenths, and twelfths of an inch on the outside face. Long measurements are usually made with steel tapes.

Measurements with a rule (*Fig.* 3)

For accurate measuring a rule should be held on its edge with the division marks on the timber. Sizes are marked exactly with a marking knife or sharp pencil. *Fig.* 3A shows how the actual reading of a length *a b* depends on the position of the eye when the rule is placed flat. *Fig.* 3B shows that the reading is independent of the eye position when the edge of the rule is placed on the surface of the material.

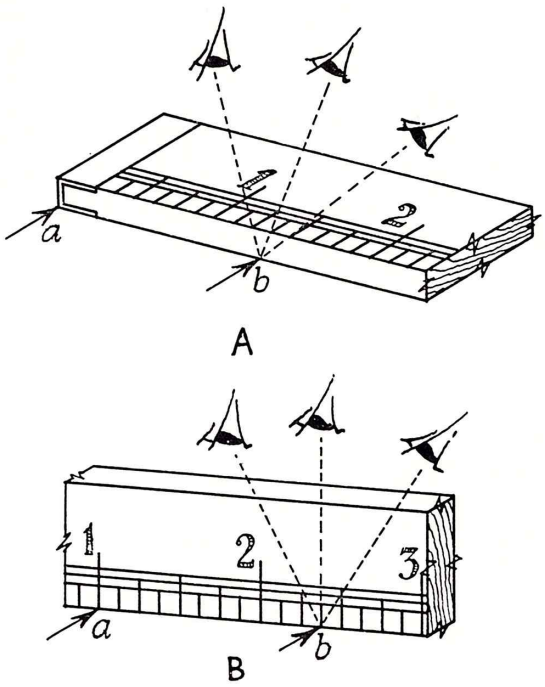


Fig. 3

Measurements with a rule

Using a rule to divide a board into equal parts (*Fig.* 4)

A board may be divided into two or more equal parts by placing the rule diagonally across the timber until the inches or half-inches are divisible by the number of parts required.

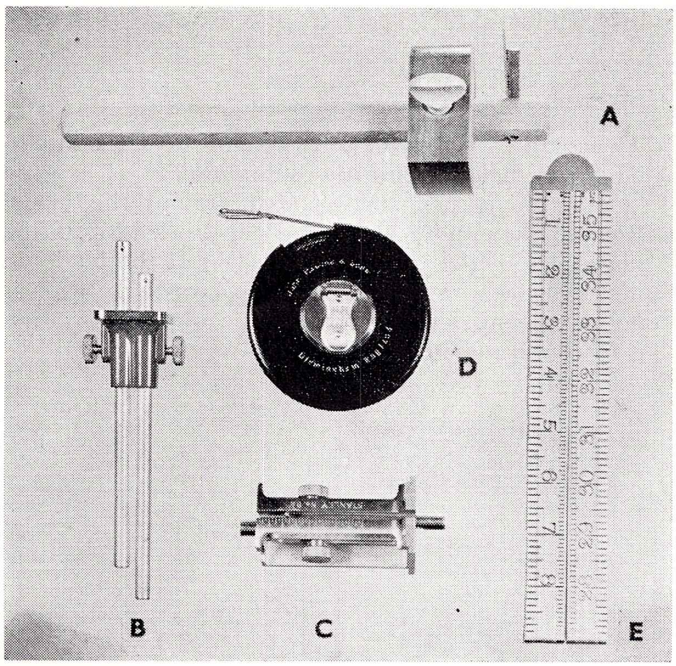


Fig. 2

Measuring tools

(A) *Cutting gauge*
(B) *Combination marking and mortise gauge*
(C) *Butt gauge*
(D) *Steel tape*
(E) *Carpenter's four-fold 3ft. rule*

Steel tape

The steel tape is a flexible ribbon of steel made in 33 ft., 66 ft., and 100 ft. lengths and graduated in feet, inches, and eighths of an inch. When used for long measurements the tape must be supported, to avoid any sag, for accurate measurements to be made.

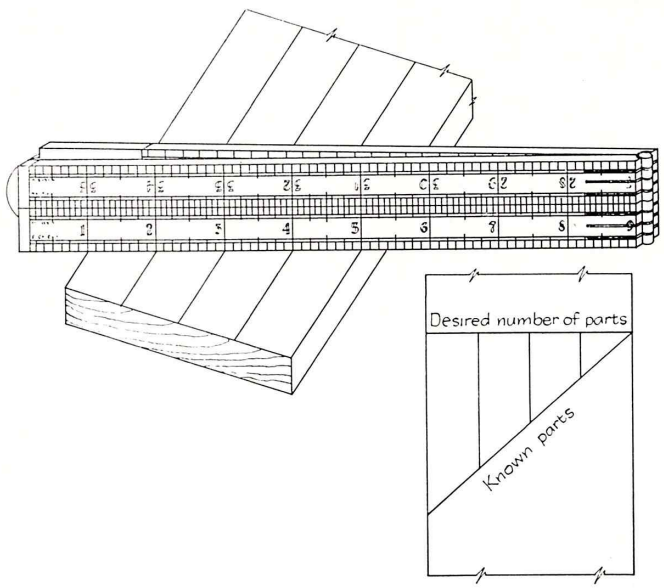


Fig. 4

Division of a board into equal parts

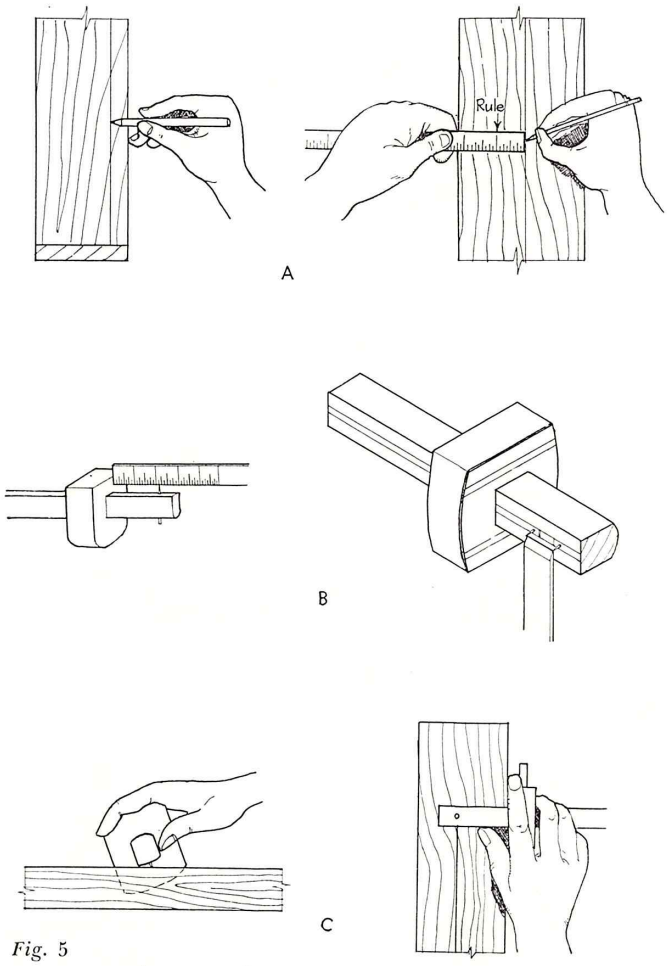


Fig. 5

(A) *Finger gauging*
(B) *Methods of setting marking and mortise gauge*
(C) *Use of marking gauge*

Cutting gauge

A cutting gauge has a cutting blade that can mark a line parallel to an end or cut thin timber.

Marking gauge

A marking gauge has a pointed spur and is used to mark a line parallel to a face or an edge.

Combination marking and mortise gauge

A combination marking and mortise gauge may be used as a marking gauge to make lines parallel to a face or an edge (e.g., gauging depths, widths, and thicknesses) or as a mortise gauge to set out two lines parallel to a face or an edge as in setting out mortise and tenon joints.

Butt gauge

When hanging sashes and doors the butt gauge is used for marking the width and depth of housings for butt hinges on jambs and stiles.

Finger gauging (*Fig.* 5A)

Finger gauging is a common method of gauging used in the trade, e.g., marking the width of a ripping or narrow piece of timber.

(c) Guiding and testing tools

Try square (Fig. 6)

The try square is used for testing or "trying" the squareness of material, and as a guide when marking lines at right-angles from the edge of a piece of timber.

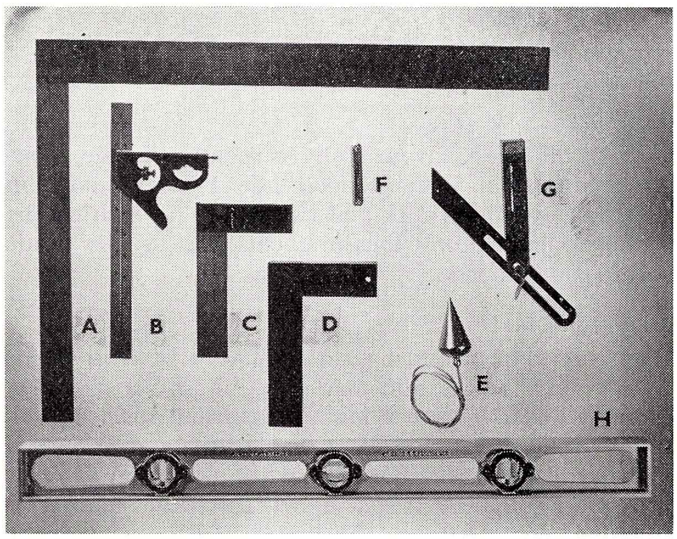


Fig. 6

Guiding and testing tools

(A) *Steel framing square*
(B) *Combination square*
(C) *Try square*
(D) *Combined try and mitre square*
(E) *Plumb-bob*
(F) *Line level*
(G) *Adjustable bevel*
(H) *Six-tube aluminium level*

Testing the try square (*Fig.* 7)

To test the accuracy of a try square the stock should be firmly held against the straight edge of a wide board, and a fine line marked around the blade. Reverse the square and place the stock against the same edge of the board. If the edges of the blade do not coincide with the lines on the board the blade is not at right-angles to the stock. The angle of variation is twice the angle of error.

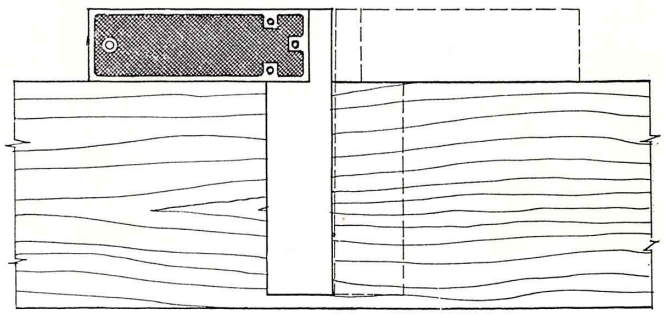


Fig. 7

Testing a try square

Combined try and mitre square

This is an all-metal tool, serving the double purpose of a try and mitre square and may be used as a guide for marking lines from an edge at angles of 45°, 90°, or 135°.

Combination square

The combination square is in common use. It has a level bubble fitted in the stock and an adjustable blade which may be fixed in position by a thumb screw. It can be used as a gauge, for marking angles of 45° and 90°, for squaring in awkward places, and for measuring depths of rebates, e.g., the rebate of a door frame.

Steel framing square

This square consists of two arms fitted together to form a right-angle. The arms are known as the body and the tongue. The body is usually 24 in. x 2 in. and the tongue 18 in. x 1½ in., but these dimensions vary with squares of different manufacturers. This square may be used as a large and accurate square, but its chief use is, with a fence attached, for setting out roof and stair work.

Adjustable bevel

The blade of the bevel is adjustable to any angle and is used for setting out and testing bevel cuts and mitres.

Spirit level

Spirit levels are made of either wood or metal. Some types have as many as six level tubes (level bubbles) for testing horizontal and vertical surfaces. The glass level tubes are slightly curved lengthwise and are nearly filled with a non-freezing spirit. When the bubble is located exactly between the two marks on the tube the level is either level or plumb, depending on the position of the tube.

Testing the accuracy of a level

The accuracy of a level may be determined by: (1) checking the level against one of known accuracy; (2) checking the level by means of the following test.

The level to be tested is placed in a horizontal position on the heads of two partly-driven nails spaced at a suitable distance. The nail heads must be adjusted in height so that the level bubble is between the two marks on the tube. The level is then turned end for end. If the level is accurate the bubble will be again exactly between the marks. Any variations may be corrected by turning the adjustment screws to be found under the cover plates. A level may also be tested in a vertical position in the manner described.

Plumb bob

This is a cone-shaped weight. It is used for testing the vertical accuracy of surfaces, e.g., for plumbing walls of buildings.

Straight edge

A straight edge is a long piece of timber (frequently Oregon pine) with parallel straight edges and of sufficient strength to remain rigid when placed on edge. It is used for testing the straightness or line of timbers; e.g., (1) testing studs or other timbers for straightness; (2) lining up the top edges of joists.

When a straight edge is used with a level for transferring levels from one point to another, it should be turned, end for end, each time it is moved to a new position. The reversing of ends has the effect of correcting any error in the level or in the straight edge.

Group 2: Cutting tools

(a) Paring and shaving tools

Planes *(Fig. 8)*

Planes are cutting tools used to produce plane or flat surfaces. (Compass and moulding planes are not included.)

German jack plane

This plane is used in preliminary operations on rough surfaces to remove an excess of material quickly. The edge of the cutting iron is curved and makes in the surface of the timber a series of shallow curved

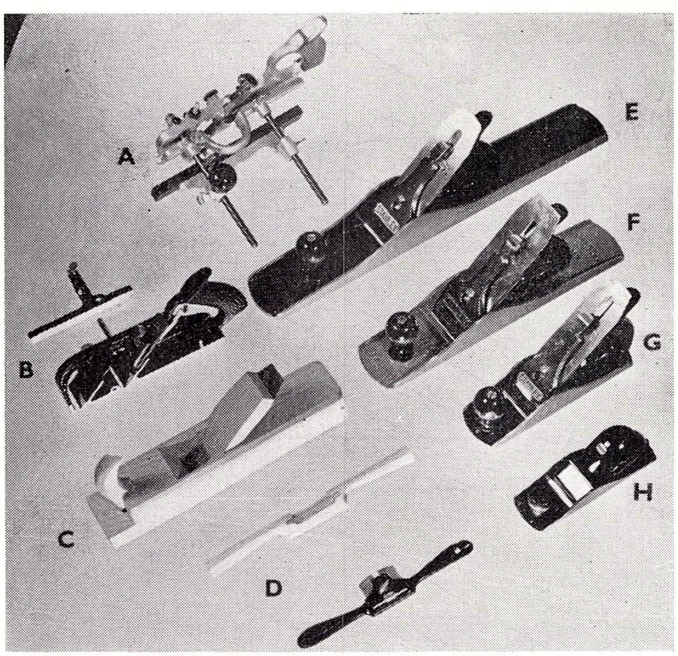


Fig. 8

Paring and shaving tools — Planes

(A) *Combination or special-purpose plane*
(B) *Rebate plane*
(C) *German jack plane*
(D) *Two types of spokeshave*
(E) *Trying or jointer plane*
(F) *Jack plane*
(G) *Smoothing plane*
(H) *Block plane*

grooves (*Fig.* 9). When a smoother surface is required it is necessary to finish with one of the planes described below.

Jack plane

The jack plane is used to remove roughness and saw marks from timber, to dress faces and edges square, and to reduce timber to the correct size.

(It gives a better finish than the German jack and is frequently used after this plane.)

Trying or jointer plane

The trying plane is used:

(1) To correct the inequalities left by the jack plane; and

(2) To true up a face to shoot edge joints;

e.g., (i) making true flat surfaces on timber (ii) shooting edge joints for pointing boards (iii) fitting doors.

Smoothing plane

As the name implies the smoothing plane is used for: (1) smoothing and finishing off flat surfaces preparatory to glass papering; (2) smoothing cross-grained areas; (3) flushing off joints and generally cleaning up work for a finish.

Block plane

The block plane is a small metal plane with its single cutting iron placed bevel side upwards and set at an angle of 20° to the sole of the plane instead of 45° as in other planes. The low pitch of the cutting iron is intended to prevent chattering when planning end grain.

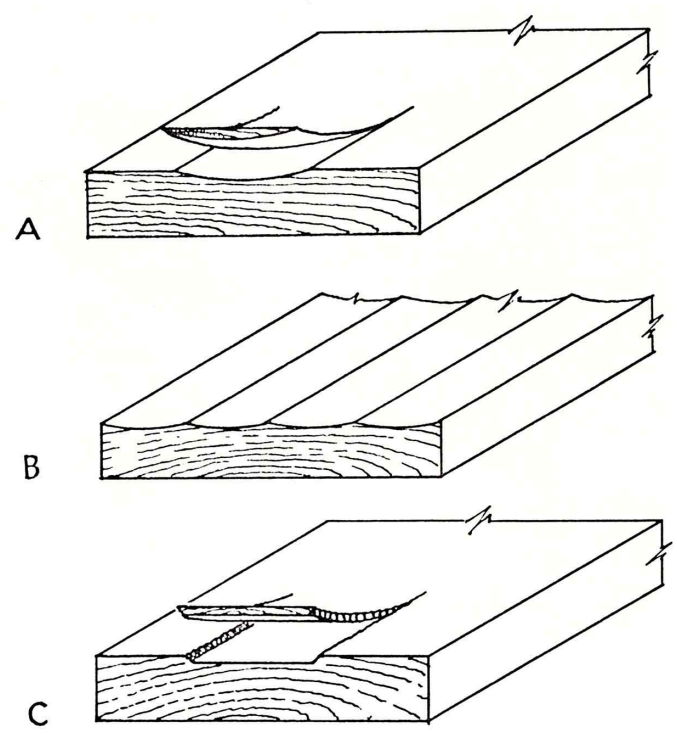


Fig. 9

(A) *Shaving cut with rounded-edge-cutting iron*
(B) *Series of grooves made with German jack*
(C) *Shaving cut with square-edge plane iron*

Spokeshave

The spokeshave is a curve-cutting plane used for producing smooth surfaces on curves and edges.

Special purpose plane

Many kinds of special-purpose planes are available but a bullnose or ordinary type of rebate plane would satisfy average requirements.

Wooden and metal planes

There has been much controvesy over the advantages and disadvantages of wooden and metal planes but the choice is largely a personal one.

Wooden and metal planes are fundamentally similar and, although some craftsmen still prefer wooden planes, it is usually conceded that meal planes are superior on account of: (1) the low position of the handle which gives better control; (2) the easy means of adjustment; (3) the hard-wearing qualities. The disadvantages are that they : (1) will rust if not kept oiled; and (2) may break if dropped; (3) have greater surface friction than wooden planes.

Metal planes — Sizes

Metal planes are obtainable in lengths of from $7\frac{1}{2}$ in. to 24 in. with cutting irons $1\frac{5}{8}$ in. to $2\frac{5}{8}$ in wide. Their construction is identical in all cases.

The following sizes are available but those sizes in brackets are most popular.

For smoothing planes Nos. 3, 4, and $(4\frac{1}{2})$
For jack planes Nos. 5, $(5\frac{1}{2})$, and 6
For trying planes Nos. 6 and (7)

Plane irons (*Fig.* 10)

Some planes have a single cutting iron and others a cutting iron and a back (cap) iron (double irons). German jack and block planes have a single cutting iron, and jack, smoothing, and trying planes have double irons.

A cutting iron is a blade of mild steel with a tool steel face, welded to its lower front edge, that provides the cutting edge.

A back iron is of steel and is secured to a cutting iron by a set screw and fits across the full width of the cutting iron. A back iron serves the purpose of: (1) curling the shaving; (2) keeping the shaving to an even thickness; (3) strengthening the cutting iron.

Fig. 10A shows a cutting iron for a German jack plane and *Fig.* 10B the slotted cutting iron for a smoothing plane.

Fig. 10C shows the back iron attached to a cutting iron and *Fig.* 10D a patent type of cap iron, the lower portion of which may be removed from the cutting iron without unscrewing the cap from the cutting iron.

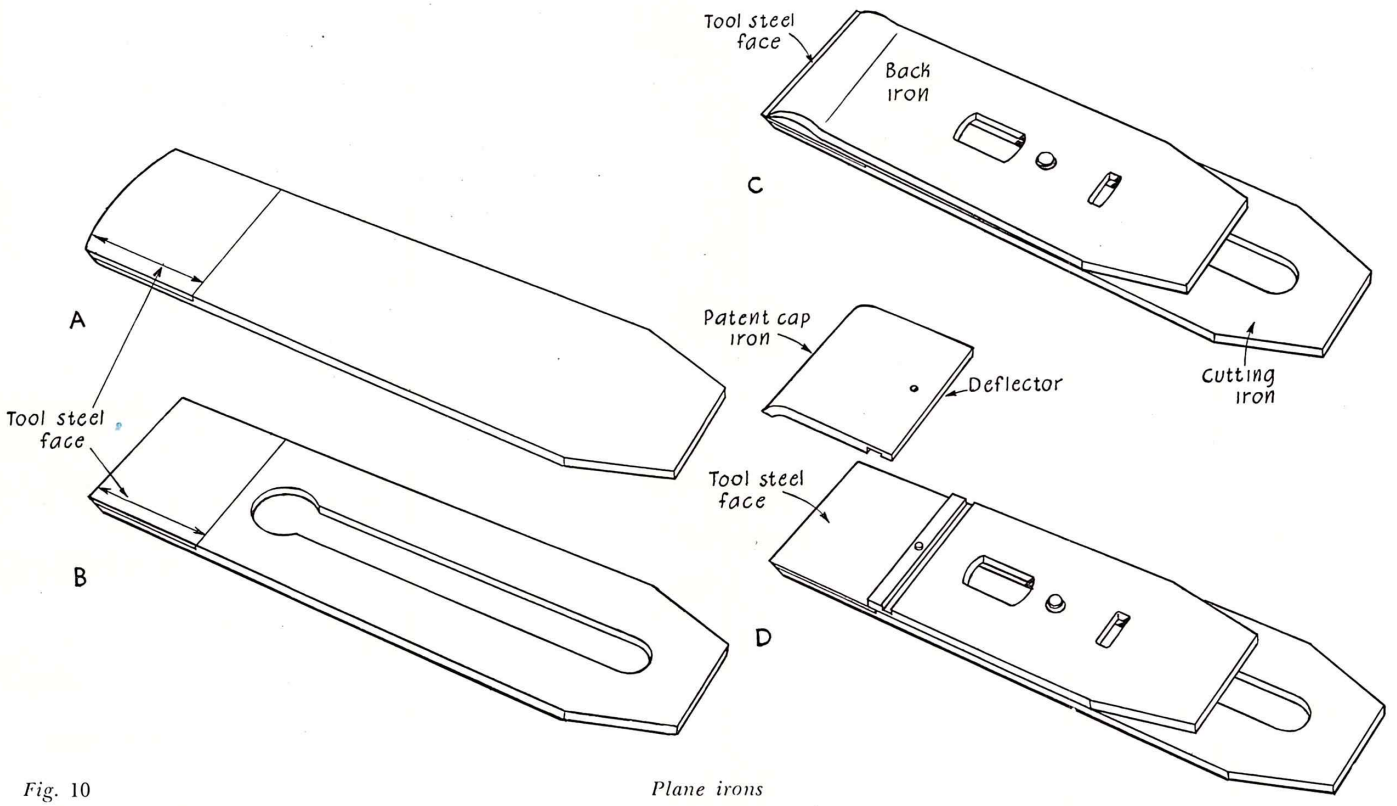


Fig. 10 *Plane irons*

(A) *Cutting iron of German jack plane*
(B) *Cutting iron of smoothing plane*
(C) *Cutting iron fitted with back iron*
(D) *Smoothing plane cutting iron fitted with patent cap iron*

Cutting action of plane irons (*Fig.* 11)

When the grain is favourable, the cutting action of a plane with a single cutting iron is comparatively smooth but under unfavourable conditions it may split the shaving from the wood in advance of the cutting edge and leave a rough surface (*Fig.* 11A). This splitting action is avoided to a large extent by fitting a back iron to the cutting iron (*Fig.* 11B). The purpose of the back iron is to turn the shaving sharply, and to break the fibres across its width. The sole at the mouth of the plane, in front of the cutting iron, holds down the wood in advance of the cutter, and helps in the breaking and turning of the shaving. The use of a back iron set close to the mouth of the plane, with sufficient room for the shaving to pass through, produces a much smoother surface on cross grain than is obtained by using a single cutting iron and a wider mouth.

A back iron must fit tightly on the face of the cutting iron so that shavings will not become lodged between the two irons.

The face of the back iron should be smooth to allow shavings to pass freely over it. The position of the back iron on the cutting iron depends on the plane, the nature of the work and the material used. The distance from the cutting edge to the back iron is $\frac{1}{16}$ in. to $\frac{1}{32}$ in. for a smoothing or a trying plane and about $\frac{1}{8}$ in. for a jack plane.

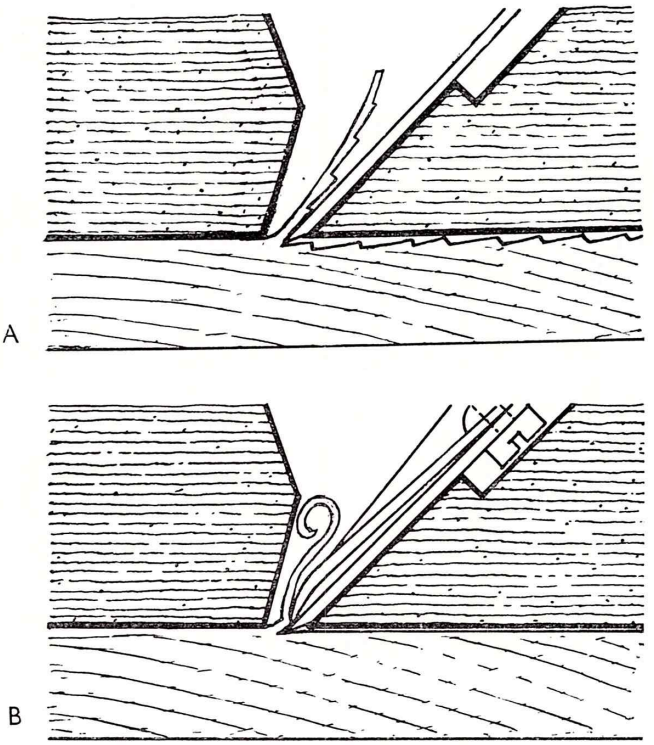


Fig. 11

(A) *Shaving split in advance of cutting edge*
(B) *Shaving weakened by back iron and close mouth*

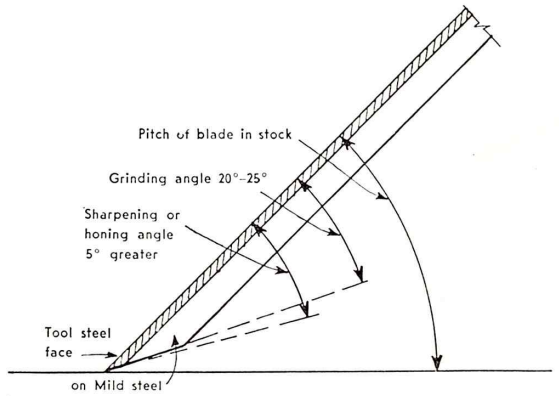


Fig. 12

Grinding and sharpening angles

Pitch of irons

The pitch of the irons in the body of most planes is 45°.

Grinding angle (*Fig.* 12)

The cutting iron of a plane is ground to an angle of 20° to 25°. Chattering may be caused if this iron is ground at too acute an angle.

Sharpening or honing angle (*Fig.* 12)

The sharpening angle should be 5° greater than the grinding angle in every case.

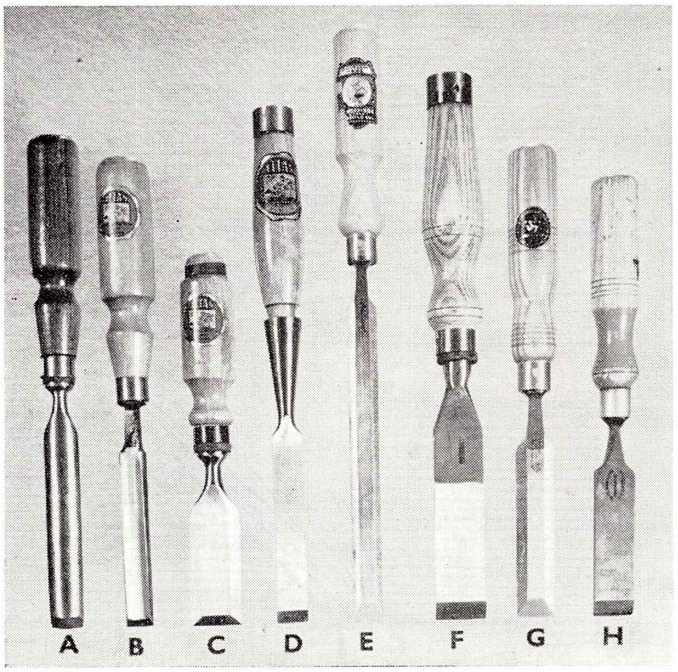


Fig. 13

Paring and shaving tools — Chisels

(A) *Firmer gouge*
(B) *Paring gouge*
(C) *Butt chisel*
(D) *Mortise chisel*
(E) *Paring chisel*
(F) *Registered firmer chisel*
(G) *Bevelled edge firmer chisel*
(H) *Firmer chisel*

Chisels (*Fig.* 13)

Firmer chisels

A firmer chisel is a strong chisel used for general purposes.

Bevel edge firmer chisel

Although it is not as strong as the square-edged chisel it is better for trenching and grooving since there is less friction on the edges.

Registered firmer chisel

The registered firmer chisel is a heavy type of firmer chisel, with a thick blade and an iron ferrule at each end of the handle. A leather washer is fitted between the shoulder and the handle to absorb the shock. It is used for heavy work such as mortising, and may be driven with a mallet.

Paring chisel

This chisel has an extra-long thin blade with bevelled edges and is used for paring work.

Mortise chisel

This chisel has a blade that is stronger than that of other chisels and is mostly used for mortising.

Butt chisel

This is a special-purpose chisel with a short bevel-edged blade. It has a leather washer on the top of the handle to enable it to be driven with a hammer. It is used by both carpenters and joiners for checking butt hinges and for a variety of light chiselling work.

Gouges

Gouges are chisels with curved cutting edges, the cutting edge being ground on the inside or the outside surface. They are made in many different sweeps or curves.

Paring or scribing gouge

The paring or scribing gouge is inside ground and used where a curved cut is made vertical to a surface, e.g., enlarging a hole — making a concave cut.

Firmer or carving gouge

Firmer or carving gouges are outside ground and used for grooving, fluting, and general carving purposes.

Rough facing tools

Hatchet

This is a general utility tool familiar to all. It is used for sharpening stakes and sometimes used for trimming edges of timber in rough work.

(b) Sawing tools

Saws for straight sawing (*Fig.* 14)

Cross-cut saw

A cross-cut saw consists of a wooden handle attached to a high-quality steel blade with a toothed cutting edge. This edge is of even thickness throughout the length of the saw and the blade is ground thinner towards the back edge to give clearance in working. The size of the saw teeth is measured by the number of teeth points to 1 in., as shown in *Fig.* 16, and this number is sometimes stamped on the heel of the saw. The choice of saw for any job depends on the class of work and the nature of the timber being sawn.

A cross-cut saw is sometimes referred to as a hand saw and is used for cutting across the grain (at right angles to the fibres). The teeth are shaped as shown in *Fig.* 29. Saws with 7 to 8 points per inch are popular for framing work.

Panel saw

Saws 24 in. and shorter are known as panel saws, the 20 in., 10 point saw being most popular among the shorter saws. It is used for fine cross cutting on finishing work, e.g., architraves.

Tenon saw

The tenon or back saw has a brass or steel rib sprung on to the back to strengthen and stiffen the blade of the saw. It is used mostly for bench work where a fine cut is required. Saws vary in length from 8 in. to 16 in. with 12 to 16 points per inch.

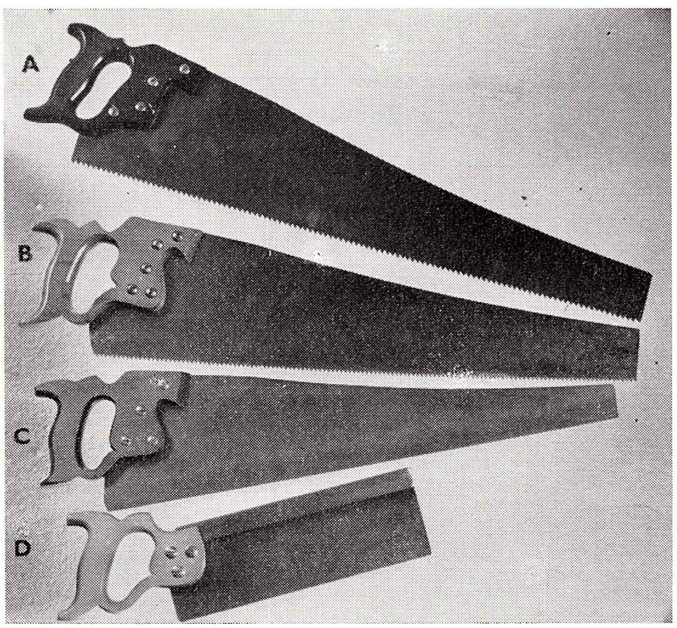


Fig. 14

Sawing tools

(A) *Rip saw*
(B) *Hand or cross-cut saw*
(C) *Panel saw*
(D) *Tenon saw*

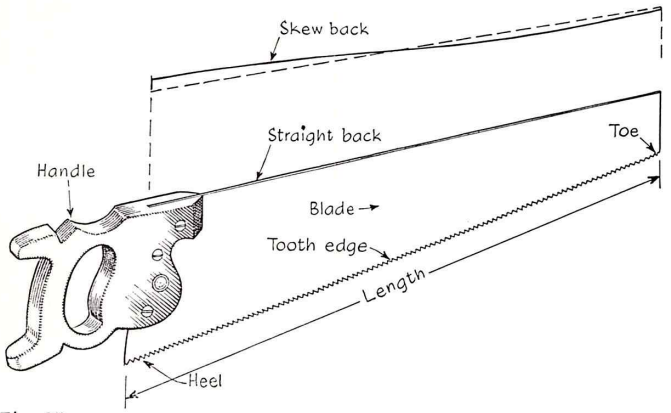


Fig. 15

Cross-cut saw

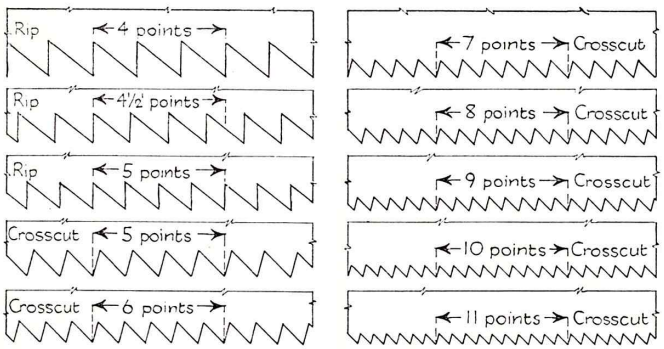


Fig. 16

Saw-teeth per inch

The coarseness or fineness of a saw is indicated by the number of saw-teeth points per inch. There is always one less tooth per inch than points per inch.

Rip saw

A rip saw is used for cutting with the grain, the operation being known as "ripping". The teeth are shaped as shown in *Fig.* 31. The $5\frac{1}{2}$ to 6 point saws are widely used.

Half-rip saw

A half-rip saw is used for framing and concrete formwork as a rip or cross-cut saw, but mostly for cross cutting, where it makes a rough but fast cut. Half-rip saws cannot always be bought as such, for they are really rip saws which have been converted by altering the teeth to a shape midway between that of a rip and a cross-cut saw. They are listed by one firm as double-duty saws.

Cross-cut, panel, and rip saws are made in the following sizes:

Sizes: 16 in. Cross-cut 10 points
18 in. Cross-cut 8, 9, 10, 11, and 12 points
20 in. Cross-cut 7, 8, 9, 10, 11, and 12 points
22 in. Cross-cut 7, 8, 9, 10, 11, and 12 points
24 in. Cross-cut 5, 6, $6\frac{1}{2}$, 7, 8, 9, 10, and 11 points
26 in. Cross-cut 5, $5\frac{1}{2}$, 6, $6\frac{1}{2}$, 7, 8, 9, 10, and 11 points

28 in. Cross-cut 5, 6, 7, and 8 points
30 in. Cross-cut 5 and 6 points
22 in. Rip 7 points
24 in. Rip 6 and 7 points
26 in. Rip 4, 4½, 5, 5½, and 6 points
28 in. Rip 3½, 4, 4½, 5, 5½, and 6 points

Curve-cutting saws (*Fig.* 17)

Compass saw

The compass saw has a blade 12 to 18 in. long. Used for cutting curves and opening cuts for bigger saws.

Keyhole or pad saws

This saw has a narrower blade than the compass saw and is used for cutting curves where other saws cannot be used, e.g., keyholes, and also for starting saw cuts from small holes preparatory to using larger saws.

Nest of saws

This consists of three blades of different types used with a detachable handle.
Keyhole blade — 10 in. long — 10 points to an inch
Compass blade — 14 in. long — 10 points to an inch
Pruning blade — 16 in. long — 8 points to an inch

Coping saw

This saw has a very fine blade held in a steel frame. It is used for scribing the ends of mouldings and cutting curves in thin timber.

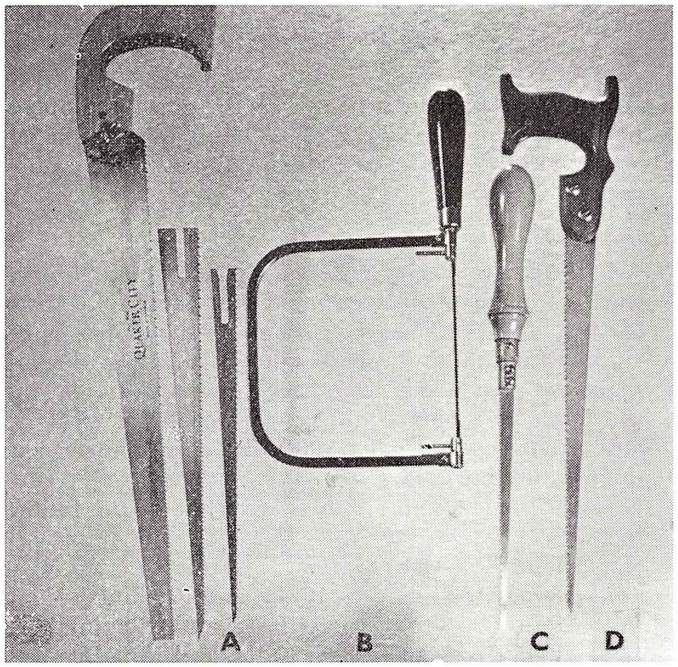


Fig. 17
Sawing tools — Curve-cutting saws
(A) *Nest of saws* (C) *Keyhole or pad saw*
(B) *Coping saw* (D) *Compass saw*

(c) Abrading and scraping tools
(*Fig.* 18)

Grindstones and emery wheels

Uses: For removing the worn edges and gaps in plane irons and chisels, etc., to form a new grinding bevel.

Grindstones

Grindstones are of quarried natural sandstones, usually about 2 to 3 ft. in diameter. They are seldom used because they occupy a lot of space, are slow cutting, and dirty to use. Water is used to wet the stone, when in use, to reduce the heat caused by friction and to wash away the particles of stone and steel. Too much heat ruins the edge of a cutting tool by destroying the temper or "burning" the metal so that a keen-edged tool will not remain sharp.

Composition abrasive wheels

These are artificial stones of emery or carborundum. When a cutting tool is being ground it should be dipped frequently into water to prevent the overheating or burning of the cutting edge. Abrasive wheels can be manufactured in different grades, e.g., soft, medium, and hard, with different degrees of coarseness and fineness. It is advisable to see the maker's recommendation.

Oilstones and oilstone slips

Uses: To put a keen edge on cutting tools.
There are two kinds of oilstones, natural and artificial.

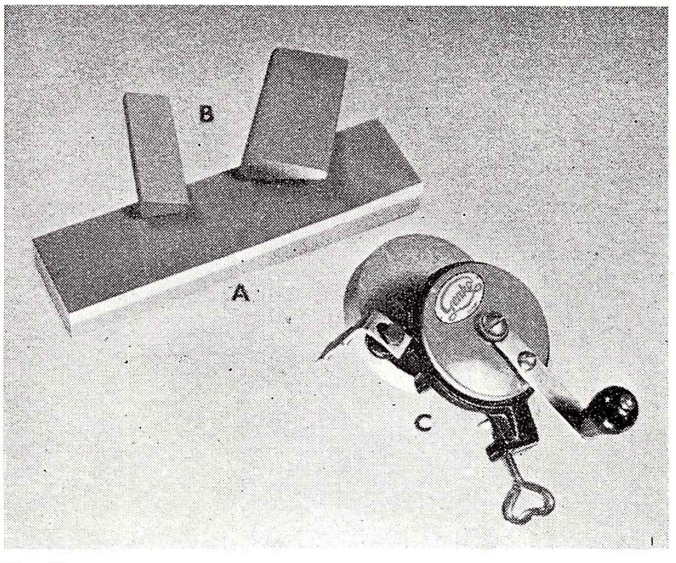


Fig. 18
Abrading and scraping tools — Grinding wheels and oilstones
(A) *Oilstone* (B) *Oilstone slips*
(C) *Portable grinding wheel*

Natural stones are silicon dioxide (SiO_2) and artificial stones are:

(1) Silicon carbide (SiC) blue crystals.

(2) Aluminium oxide (Al_2O_3) brown crystals.

Natural oilstones, over the past few years, have been difficult to obtain, the artificial oilstones having largely taken their place on the market. Artificial oilstones may be graded in fine, medium, and coarse, and in a combined form with fine on one side and coarse on the other.

A very light free-flowing mineral oil or kerosene mixed with a light machine oil is the best type of oil to use on an oilstone.

Other abrading and scraping tools (*Fig.* 19)

Hand scraper

It is used to remove plane marks and to produce a very smooth surface.

Abrasive papers

Abrasive papers consist of powdered abrasive materials glued to stiff paper. They should mostly be used with a cork block or rubber, to provide a flat surface.

Glass paper

Glass paper is used chiefly for hand smoothing of wood. The abrasive material may be powdered glass, flint, or quartz. Glass paper is supplied in 12 in. x 10 in. sheets.

Grades: 00 or Flour, 0, 1, 1½, Fine 2, Medium 2, Strong 2, 2½, 3.

As a general guide M.2, a coarse grade of paper, is used for preliminary smoothing, followed by the finer papers No. 1 or 1½. Flour paper is extremely fine and mostly used in french polishing work.

Garnet paper

Used for both hand and machine sanding — supplied in 11 in. x 9 in. sheets and in rolls, belts, discs, etc. Abrasive grains are natural crushed garnet stone.

Grades (sheets) 8/0, 7/0, 6/0, 5/0, 4/0, 3/0, 2/0, 0, ½, 1, 1½, 2, 2½, 3, 3½.

Grade 8/0 is extremely fine and grade 3½ very coarse. Those papers that would be used in hand work on timber would grade 0, ½, 1. Comparing this paper with glass paper, grade ½ garnet paper is of the same coarseness as M.2 glass paper, and 3/0 garnet paper the same as No. 1 in glass paper.

Aluminium oxide paper

These abrasive papers are mostly used for machine sanding but may be obtained in 11 in. x 9 in. sheets for hand work. Grades range from 9/0 (very fine) to 3 (coarse).

Silicon carbide paper

With the exception of floor surfacing this kind of abrasive paper is not generally used for woodworking. The abrasive is very hard and durable.

Emery paper

This is mostly used in the metal-working trades.

Files

Files are shaped lengths of hardened cast steel on which teeth have been cut to form an abrading surface. They are available in various shapes, cuts, and grades. The shapes may be flat, round, triangular, half-round, etc., and either parallel or tapered.

The cut of a file relates to the nature of the teeth. Files may be single cut, double cut, or rasp cut.

The degree of coarseness or fineness of the teeth is graded as rough, bastard, second cut, smooth, and dead smooth.

To produce a fine finish the type of file to be used after a rasp would be an 8 in. half-round, double cut, smooth file.

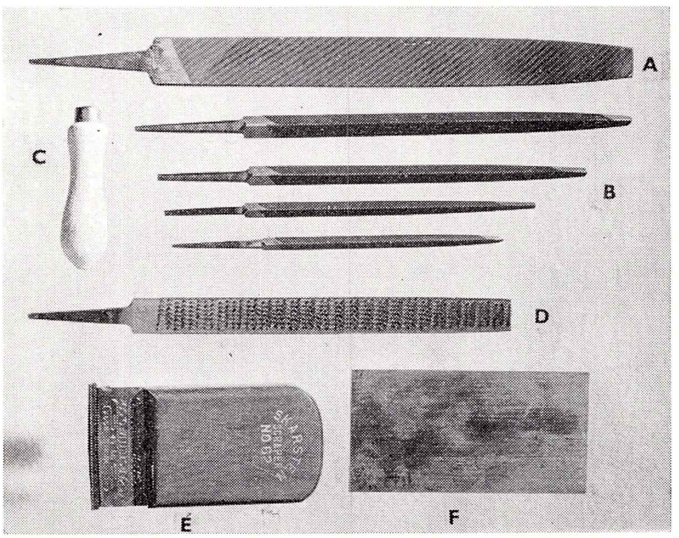


Fig. 19

Abrading and scraping tools — Files, rasps, and scrapers

(A) *Mill file*
(B) *Slim taper saw files*
(C) *File handle*
(D) *Rasp*
(E) *Patent scraper*
(F) *Cabinet scraper*

Rasp

A rasp is a type of file, usually half-round in section, used to remove wood fairly quickly. It leaves a rough surface which must be finished with a file and glass paper.

Its main uses are for preliminary rough shaping on curved surfaces. Rasp-cut teeth differ from both single-cut and double-cut teeth in that they are not placed in parallel rows across the file but each tooth is formed separately by a single pointed tool or punch.

(d) Boring tools

(*Fig.* 20)

Bits

Bits for boring tools are of three main kinds: (1) twist bits; (2) centre bits; (3) wood drills.

Twist bits

Twist bits are desinged with a twisted point which draws the bit into the wood and a twisted shank which ejects the waste wood and keeps the hole straight.

Sizes: $\frac{1}{4}$ in. to $1\frac{1}{4}$ in., increasing by sixteenths.

A type of twist bit without spurs or scribers is made especially for hard-textured woods and the ordinary type with scribers is for soft-textured woods.

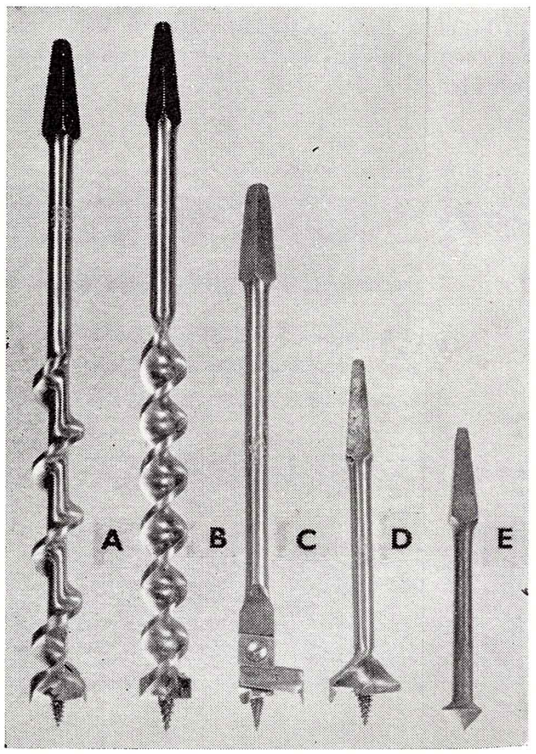


Fig. 20

Boring tools

(A & B) *Types of twist bit*
(C) *Expanding bit*
(D) *Centre bit*
(E) *Countersink bit*

Centre bit

The centre bit has a centre point (sometimes threaded), a scriber, and a router. It is used mostly for boring shallow holes through thin timber.

Expanding bit (sometimes called expansive or expansion bit)

There are several sizes of expanding bits available and two cutters are supplied with each bit. Small sizes bore holes from $\frac{1}{2}$ in. to $1\frac{1}{2}$ in. in diameter and the largest holes up to 3 in. This type of bit has an advantage over other bits in that it can be adjusted to any sized hole within its capacity.

Wood twist drills

These drills are similar to metal drills except that they are longer and the grinding angle at the point of the wood drill is about 60°. They have square taper shanks as other brace bits.

Dowel bit

The dowel bit is a twist bit usually shorter than the ordinary twist bit. Its main use is for boring holes for dowels.

Dowel pointer

A dowel pointer is used for pointing the ends of dowels.

Countersink bit

Countersinks are used for enlarging the tops of holes for the heads of countersunk screws.

***Group 3:* Percussion and impelling tools**

(*Fig.* 21)

Claw hammer

It is used for driving and withdrawing nails.

Mallet

This is for driving chisels. A carpenter rarely uses a mallet, preferring to use the side of a claw hammer for driving chisels.

Nail punch

It is used in conjunction with a hammer to drive the heads of nails below the surface of the timber.

Screwdrivers

Screwdrivers are available in a variety of sizes and patterns, and are used for inserting and withdrawing screws. The spiral ratchet screwdriver (*Fig.* 21) has a ratchet fitted and also may be extended in length.

Screwdriver bit

A screwdriver bit has a square taper shank at one end and is shaped like a screwdriver at the other end. It is held in a brace and its main use is in inserting and withdrawing screws faster and with greater force than is possible with the usual screwdriver.

Hand brace

The brace can also be regarded as a holding tool.
Uses: To hold and give leverage in a continuous rotary motion to the various bits. A ratchet is fitted which enables the handle of the brace to be moved in a small arc as well as a full circle.

Automatic push drill

It is used for boring holes for nails and screws. Various sizes of bits are carried in the handle of the drill.

Hand drill

This can be used in places where it would be impossible to use an ordinary brace. Small sizes of parallel shank twist drills are used in the drill.

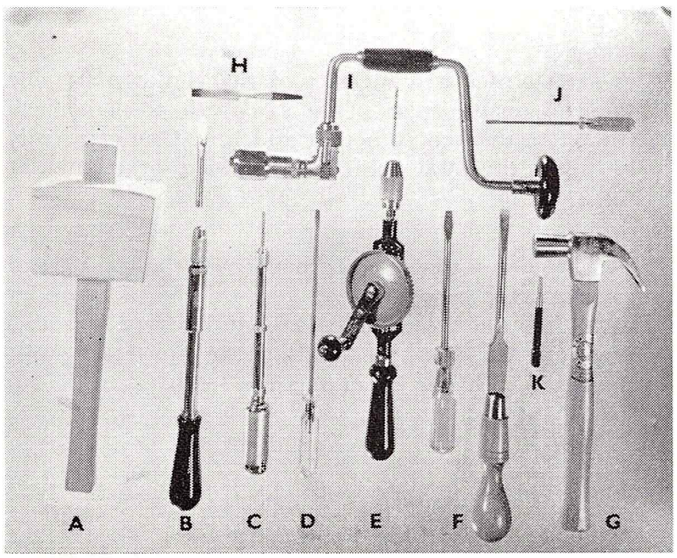


Fig. 21

Percussion and impelling tools

(A) *Carpenter's or joiner's mallet*
(B) *Spiral ratchet screwdriver*
(C) *Automatic push drill*
(D) *Transparent handle screwdriver*
(E) *Hand drill*
(F) *Two types of screwdriver*
(G) *Claw hammer*
(H) *Screwdriver bit*
(I) *Hand brace*
(J) *Small screwdriver*
(K) *Nail punch*

Group 4: Holding or supporting tools

(*Figs.* 22 *and* 23)

The bench

This is used for supporting the work during the various operations of construction.

The vice

The vice is attached to the bench and is used to hold pieces of timber while they are fashioned to shape.

Cramps

Bar and G cramps hold and cramp timber together.

Saw grip (or saw vice)

This is usually a wooden grip used to hold saws during sharpening.

Mitre box

This is an appliance used for guiding a saw and holding pieces of timber while mitres and other angles are being cut.

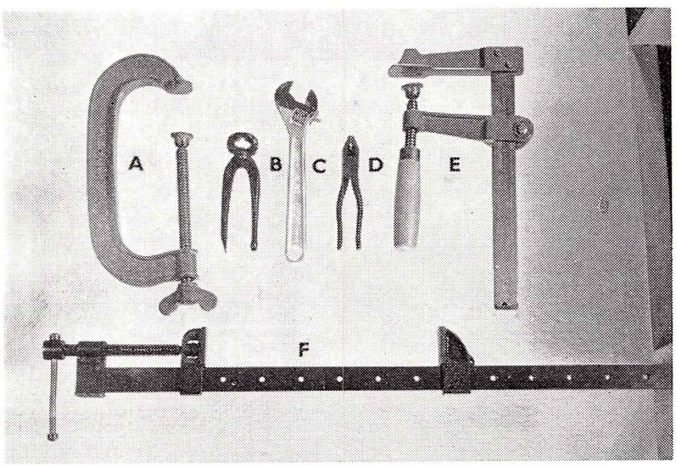


Fig. 22

Holding and supporting tools

(A) *"G" cramp*
(B) *Pincers*
(C) *Adjustable spanner*
(D) *Pliers*
(E) *Quick-release cramp*
(F) *Bar cramp*

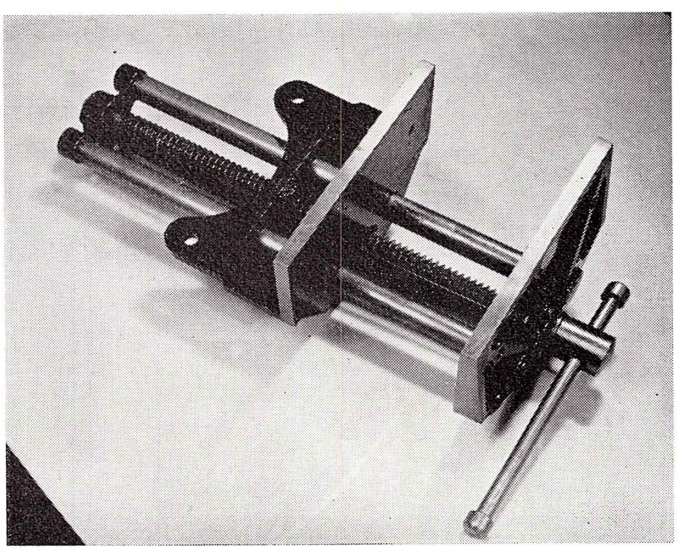


Fig. 23

Bench vice

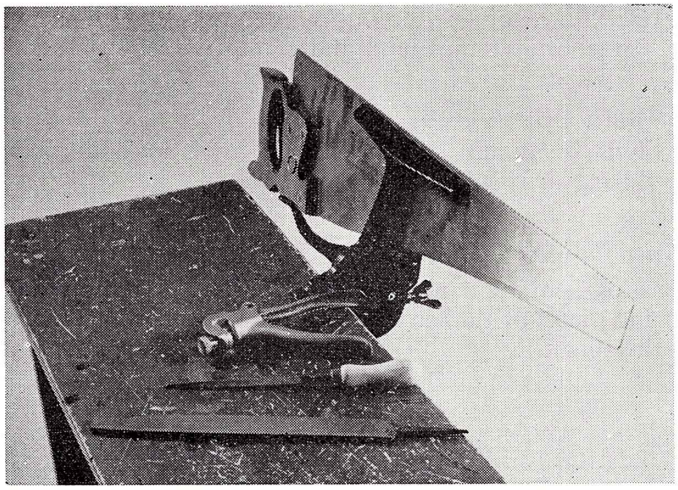


Fig. 24

Tools for saw sharpening

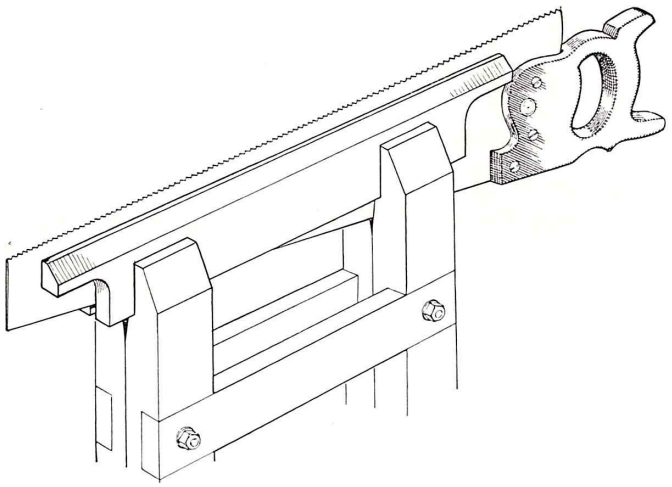


Fig. 25

Wooden saw grip

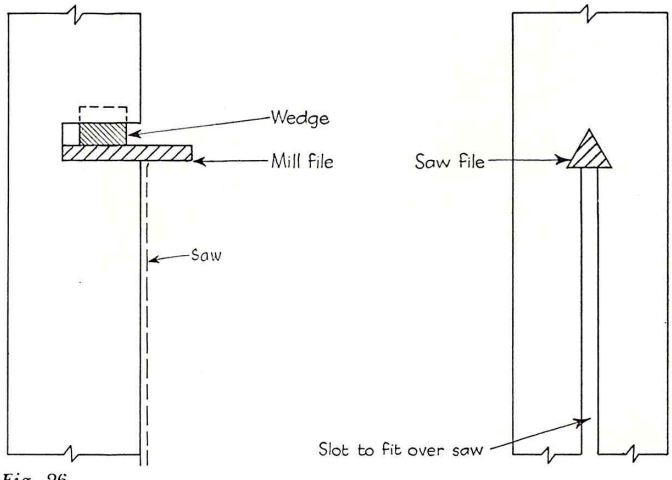


Fig. 26

Simple jointers

Tools for saw sharpening
(*Fig.* 24)

The tools required for saw sharpening include:

(1) Saw grip
(2) Saw jointer
(3) Saw set
(4) Flat file
(5) Slim taper triangular file
(6) File handle

Description and uses

(1) Saw grips hold a saw in a rigid vertical position during filing. A metal type of saw grip or vice is available but a carpenter often makes one of wood. (*Fig.* 25).

(2) A saw jointer is a metal tool that holds a flat file squarely on the edges of the saw teeth, to make each row of teeth even in height and line. One can easily be made of wood using either a flat or triangular file (*Fig.* 26).

(3) A saw set is a tool used to bend over the top part of each saw tooth so that the kerf will be of a proper width for the saw blade. A popular type has two plungers, one plunger holding the saw set against the saw, while the other sets the teeth.

Files

The following files are used:

Jointing: 8 in. to 10 in. flat, smooth file.

Sharpening: The following table indicates the file to be used:

$4\frac{1}{2}$, $5\frac{1}{2}$, 6 points – 7 in. slim taper triangular file
7, 8 points – 6 in. slim taper triangular file
9, 10 points – 5 in. or 6 in. slim taper triangular file
11 to 15 points – $4\frac{1}{2}$ in. slim taper triangular file

(4) *File handles*

Handles may be of wood or metal. Wooden handles are fitted with a brass ferrule and should be of a convenient size to suit the operator's hand.

Metal handles have a thumb-screw for fixing the tang of the file in the handle.

As a file is very brittle it should not be driven with a hammer into the handle. The handle is pushed over the tang and the butt end of the handle given a tap on the bench.

Saw Sharpening

The five steps in the sharpening of saws are: (1) jointing or stripping; (2) reshaping; (3) setting; (4) filing; (5) side dressing.

(1) *Jointing* (*Fig.* 27A, 27B)

Jointing is the process of reducing saw teeth to an even height and line. The jointer is lightly passed back and forth until the file touches the top of every tooth. For rip, hand, and panel saws the line of the teeth is slightly rounded from heel to toe. As little metal as possible is taken off in jointing.

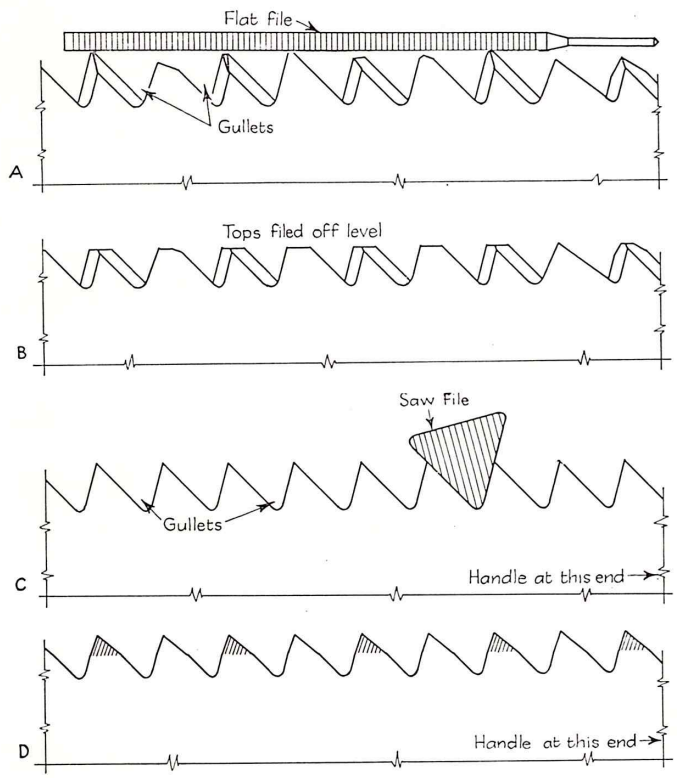


Fig. 27

Sharpening cross-cut saws

(A) *Jointing or stripping. Keep file flat on teeth*
(B) *Result of stripping. Cutting edge slightly rounded from heel to toe*
(C) *Reshaping of teeth (if necessary) file straight across*
(D) *Setting.*

(2) *Reshaping* (*Fig.* 27C)

The object of this is to reshape each tooth and also to make the gullets of equal depth. Reshaping is required only when the teeth have become irregular through continued sharpening, or when a large amount of metal has been removed in jointing.

The saw should be placed in the saw vice with the gullets about $\frac{1}{8}$ in. above the jaws of the vice. The teeth are then filed in each successive gullet, from one side of the saw, and square across at right angles to the blade. The teeth are not bevelled at this stage.

(3) *Setting* (*Fig.* 27D)

Setting of a saw consists in bending over the upper part of each tooth, one to the left and the next to the right. This makes the cutting edge of the saw wider than the blade and thus allows a clearance in working. Although some saws are ground thinner on the back edge (taper ground) they still need a slight amount of set. Generally the maximum amount of set should not exceed one-half the thickness of the saw blade and varies according to whether wet and soft timber, or hard and dry timber is sawn. The relative size of teeth has a bearing on the amount of set given, rip saws requiring less set than cross-cut saws. Medium-sized teeth should be set about one-half way down from the points to their base and coarse teeth, such as those on a rip saw, about one-third of the way. In cold weather the blade of the saw should be warmed before setting to prevent teeth breaking. It is not necessary to reset the teeth of a saw every time they are sharpened, but setting is always necessary after jointing and shaping.

(4) *Filing*

When a saw has been jointed and reshaped the top of each tooth will have a small flat instead of a point. If a saw is to be sharpened without these first operations, a flat file is passed lightly along the tops of the teeth to form a *very small* flat on the top of each tooth. These flats serve as a guide in filing; the object of which is to reduce the small flats to cutting edges and, in the case of cross-cut saws, sharp points. When filing the first side, only file half the flat away; otherwise, when the other side is done, one set of teeth is liable to be filed too low, which would cause the saw to cut to one side.

Filing cross-cut saws (*Fig.* 28)

(i) Fix the saw in the saw grip with the *handle to the right* and the bottoms of the gullets of teeth about $\frac{1}{8}$ in. above the jaws of the vice. If more of the blade projects the file will chatter.

(ii) Stand in the position as shown in *Fig.* 28A and commence filing at the toe of the saw. Place the file in the gullet to the *left* of the first tooth bent towards you and with the file at an angle between 45° and 70° to the blade of the saw. On the push stroke, file both teeth on each side of the file at the same time until half the flat on each tooth is removed. Holding the file at the same angle file each alternate gullet as far as the handle of the saw. The saw blade is moved through the clamp periodically so that the teeth being filed are always held rigidly by the clamp.

(iii) Turn the saw around in the vice so that its

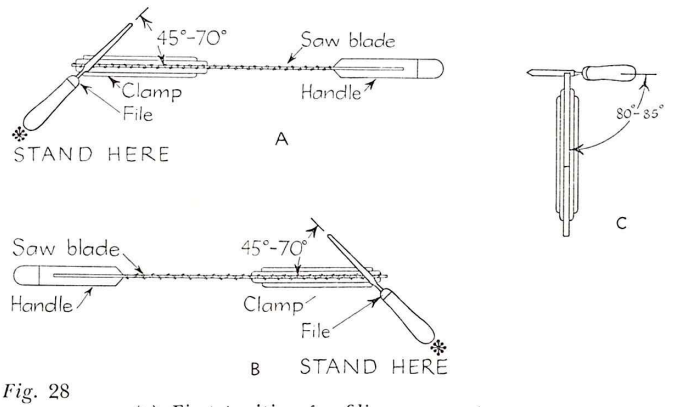


Fig. 28

(A) *First position for filing cross-cut saws*
(B) *Second position for filing cross-cut saws*
(C) *End view*

handle is on the left (*Fig.* 28B) and place the file in the gullet on the *right* of the *first* tooth bent towards you at the toe of the saw and file each alternate gullet at the same angle as before. File until the remaining half-flat is removed and a needle-point is formed on each tooth.

The teeth of a cross-cut saw vary to a slight extent in shape, angles, bevel, and set on saws used for dry, seasoned timber, wet or green timber, hardwoods and softwoods. For best results in sharpening all but the most experienced should follow step by step the instruction given above.

A new cross-cut saw or one that has been sharpened properly should have teeth of the shape shown in *Fig.* 29. The angle of a tooth is 60°, the front edge being 15° from the perpendicular and the back edge 45°.

Filing rip saws (*Fig.* 30)

With one exception this operation is exactly the same as that given for cross-cut saws. This exception is that with rip saws the file is held straight across the saw at right-angles to the blade. The file should be placed in the gullet to keep the angle on the front of each tooth 8° at the front and 52° (from perpendicular) at the back. (*Fig.* 31.)

The saw is fixed in the vice with the handle to the right. Start at the toe and place the file in the gullet to the left of the first tooth set towards you.

Continue to place the file in every second gullet and file straight across along the length of the saw blade. Turn the saw around in the vice and starting at the toe, file first the gullet missed (when filing from the other side) and continue to file in every second gullet along the saw blade.

The final result is the chisel-edged teeth necessary for a rip saw, filed to the angles shown in *Fig.* 31.

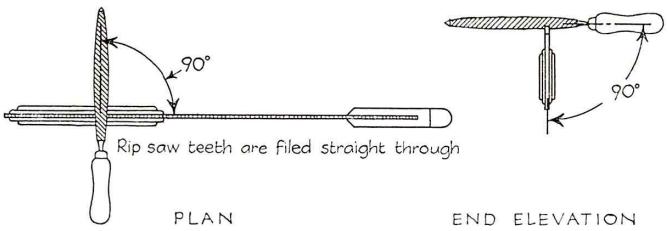


Fig. 30

Position for filing rip saws

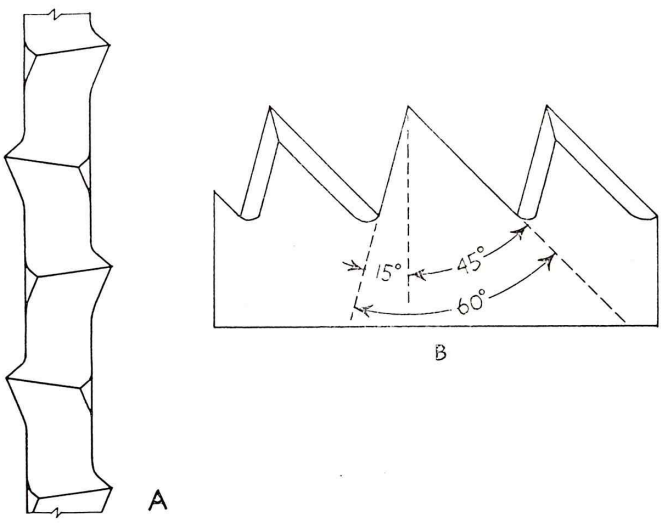


Fig. 29

Cross-cut saw teeth

(A) *Top view* (B) *Side view*

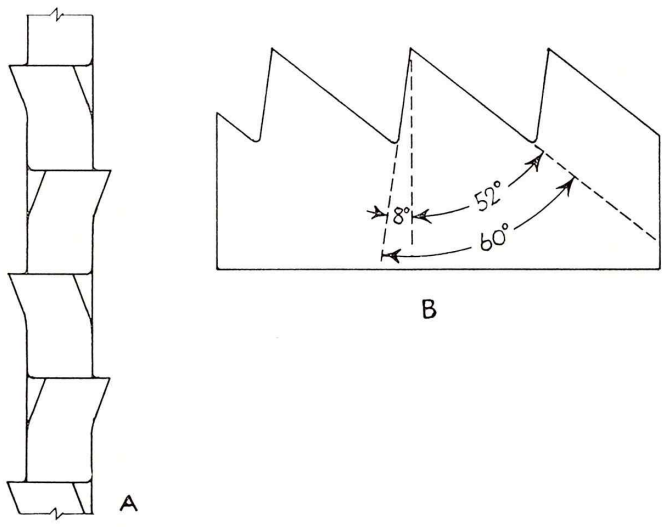


Fig. 31

Rip-saw teeth

(A) *Top view* (B) *Side view*

(5) *Side dressing*

After a saw has been filed it is usual to side dress it to even up the irregularities of setting and filing. This is done by laying the saw on a flat surface and rubbing, once or twice, with an oilstone along each face of the blade on the edges of the teeth.

Shape and action of saw teeth

Cross cutting

The teeth of a cross-cut saw sever the fibres on each side of the saw cut. The inside edges of the teeth pare the centre portion of the groove (kerf) and the waste is carried away as sawdust. The action of the teeth is that of a series of knives (*Fig.* 32A, 32B).

Ripping

In this case the teeth are shaped as shown in *Fig.* 31. The action of rip-saw teeth is more like a series of planes than of knives, each tooth cutting a shaving the full width of its edge, and carrying it out of the groove in front of it (*Fig.* 32C, 32D).

Use of saws

The proper position for cross cutting is shown in *Fig.* 33 where an imaginary line extends from the eye down through the saw. Between the face of the board and the edge of the saw an angle of 45° is recommended. Other points on using cross-cut saws are illustrated in *Fig.* 33.

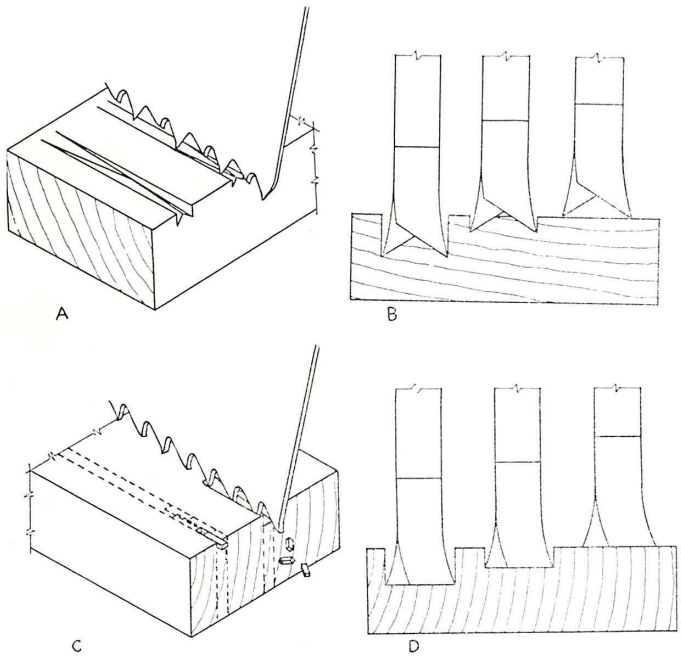


Fig. 32

Cutting action of cross-cut and rip saws

(A) *Knife-like edges of cross-cut saw. First score a groove then deepen it*
(B) *End view of saw teeth (enlarged) showing cutting action*
(C) *Rip-saw teeth cut like vertical chisels (or a series of planes)*
(D) *End view of saw teeth (enlarged) showing shape of saw cut*

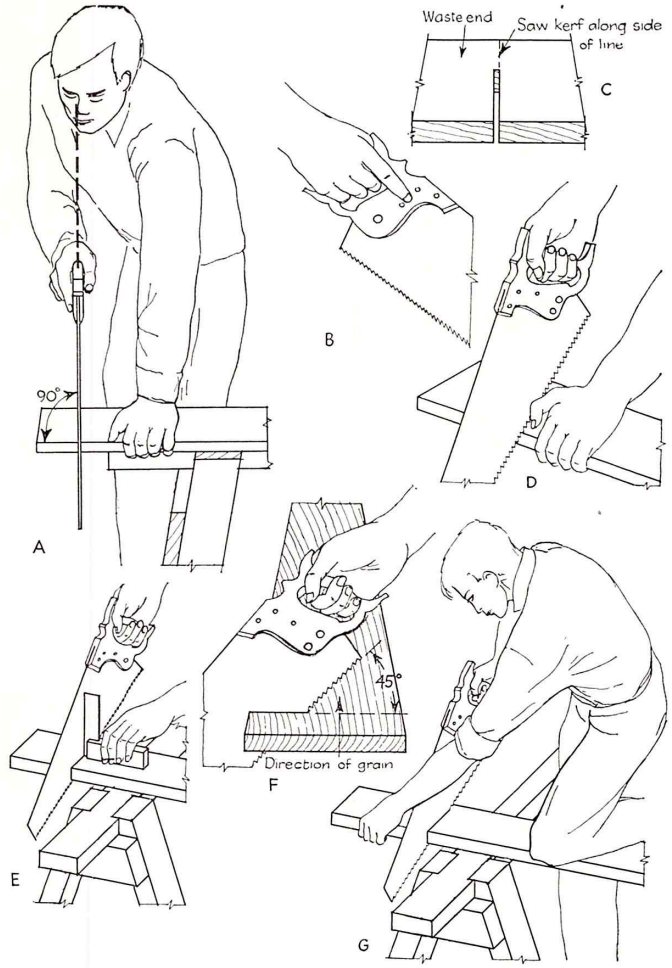


Fig. 33

Use of cross-cut saw

(A) *Position for sawing*
(B) *Index finger points towards toe of saw*
(C) *Commence sawing alongside the line*
(D) *Use thumb knuckle when starting the saw cut*
(E) *Checking position of saw with try square*
(F) *Sawing angle for cross-cut saw*
(G) *Waste end of board being held to prevent it breaking off*

The correct position for ripping is shown in *Fig.* 34. As with the cross-cut saw a sight is taken down through the saw with the body in position to permit long easy strokes. Note the angle of the saw with the face of the work.

In ripping or cross cutting, it is good practice to cut on the waste side of the line instead of trying to halve the line.

Grinding and Sharpening Cutting Tools

A keen cutting edge is produced on a plane iron or chisel by first grinding the edge to shape on a grindstone and then producing a keen cutting edge by sharpening, or honing on an oilstone.

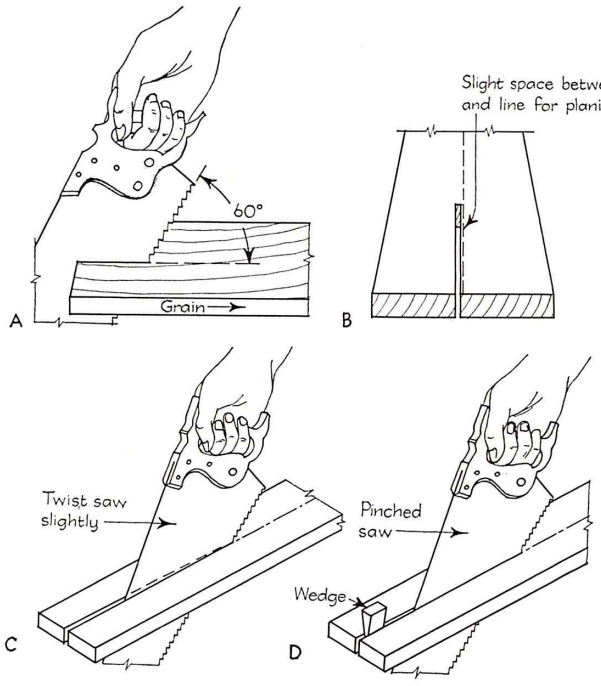


Fig. 34

Use of a rip saw

(A) *Sawing angle for rip saw*
(B) *Position of saw cut*
(C) *Widening the saw cut*
(D) *Use of wedge to open cut*

After a cutting edge has been resharpened several times it becomes rounded and the edge must be re-ground. Unless the edge is gapped, it is necessary only for it to be ground until approximately $\frac{1}{64}$ in. of the old sharpening bevel remains, thus avoiding damage to the cutting edge and needless wear on the blade. If, however, the cutting edge is gapped, it must then be re-ground so that the gaps are entirely eliminated. (*Fig.* 35).

Grinding

Grinding is carried out on either a sandstone grindstone or an emery wheel, which quickly produces a bevel of correct shape, but with the edge not sufficiently sharp for use.

The grinding bevel of plane irons and chisels is generally from 20° to 25°. Before the cutting edge of the tool is ground to the correct bevel, the edge should be squared with the side of the blade and any gaps removed by lightly touching the edge against the grindstone or emery wheel.

The blade of the tool is held to the grinding wheel at the required angle and moved squarely across the face of the wheel during the grinding process. A tool rest may be used to hold the tool at the desired angle. The edge of the blade must be kept cool by continuously dipping it in water, unless the wheel is running in water or a water spray is being used. Care must be exercised, particularly when using an emery wheel, to prevent the overheating of the edge, as shown by a bluish colour. Such overheating "draws the temper" of the steel and softens it.

Remember that it is necessary only to grind out the sharpening bevel, unless the iron is gapped or out of square, in which case the cutting edge is tested with a try square as the grinding proceeds.

Sharpening or honing

A tool must have a sharp edge if it is to produce a smooth, true surface quickly and easily; so the ground edge must be sharpened. Sharpening, or honing, is done more frequently than grinding, in fact whenever the edge needs to be "touched up".

An oilstone is necessary to sharpen cutting tools. The surface of the oilstone is kept wet with a light non-drying oil during sharpening. A correct pitch for sharpening may be obtained by bedding the ground bevel of the blade on the oilstone and then slightly raising the back edge of the bevel.

With a strong even pressure the blade is rubbed back and forth, with a sliding rotary motion, along the full length of the stone. The usual practice is to make the sharpening bevel about 5° greater than the grinding bevel. Rubbing or sharpening should be continued until no line of reflected light is visible on the cutting

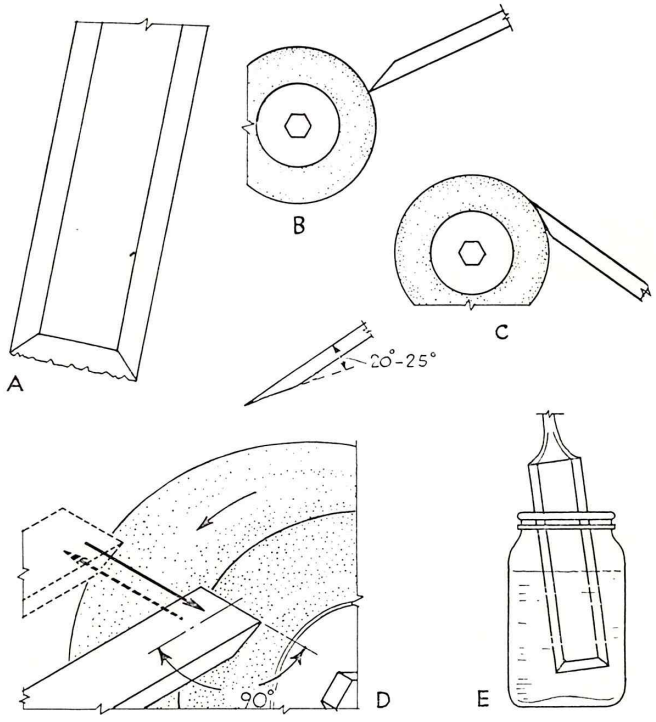


Fig. 35

Grinding-edged tools

(A) *Gapped chisel*
(B) *Gaps are removed and edge squared with sides by touching it lightly against the grinding wheel*
(C) *Bevel is ground to an angle of about 25°*
(D) *Edge of chisel guided across the face of the wheel*
(E) *Blade of chisel must be frequently plunged in water to keep edge cool during grinding process. A blue colour indicates loss of temper*

edge. When examining the blade for the "white edge", it is best to tilt it backwards and forwards to catch the light.

Continuing further, the white edge will disappear and a burr or wire edge will form on the flat side of the blade. This must be removed; so the blade is turned over and rubbed, absolutely flat, backwards and forwards two or three times. Finally the blade must be stropped on a piece of leather or against the palm of the hand.

Test of sharpness

The cutting edge, if sharp, is invisible when held to the light. A test of the sharpness may be made by drawing the edge of the tool across the thumb nail; if the cutting edge slides it is not sharp; if it drags the edge is sharp.

Sharpening gouges

Outside gouges are sharpened in a similar manner to chisels. The gouge is rolled backwards and forwards to grind the bevel and an oilstone slip is used to remove the burr on the inside concave surface. Inside gouges are ground on a curved stone and honed to a keen edge with an oilstone slip.

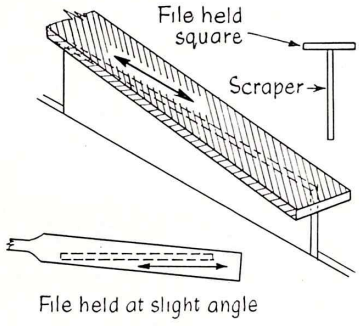
Hints on sharpening

For a quick, razor-like edge:

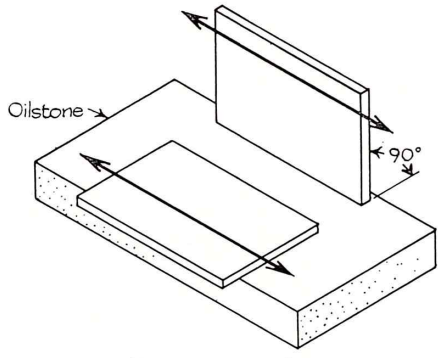
(1) The oilstone must be clean.
(2) The oil must be thin.
(3) Pressure must be light.
(4) If rubbing is likely to be prolonged use a coarse stone first.
(5) If rubbing is likely to be brief use a fine stone.

Sharpening cabinet scrapers (*Fig.* 36)

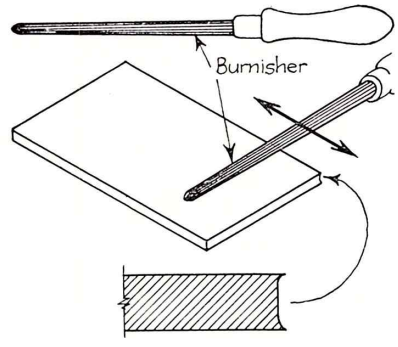
(1) Place the scraper in the vice and square the edges with a flat file.
(2) Complete the process of squaring the edges by rubbing the scraper on an oilstone.
(3) With the scraper on its flat draw the edges on both sides with a burnisher, nail punch, or gouge.
(4) Turning of the edges may conveniently be done with the scraper in the vice. The edges are first flattened as shown and then turned, thus producing an edge as shown. One firm movement of the burnisher is usually sufficient to turn the edge. For satisfactory use the scraper should be held to the scraping angle shown.



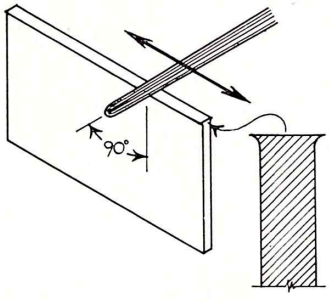
1. Squaring the edge



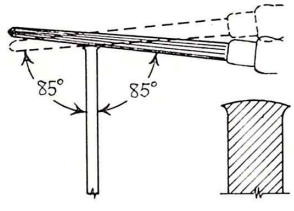
2. Honing the edges



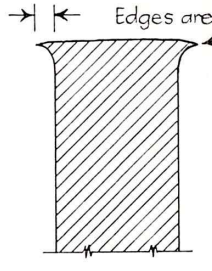
3. Drawing the edges



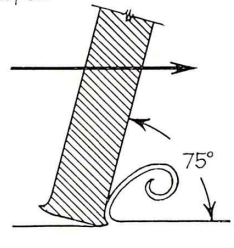
4. First stroke to flatten edge



5. Final turning strokes



6. Sharpened scraper



Scraping angle

Fig. 36

Method of sharpening cabinet scraper

Sharpening blades of spokeshaves

The blade of a metal spokeshave is sharpened in the same way as a plane iron, but the tanged type of spokeshave blade must be first ground on a narrow grinding wheel, and then sharpened with an oilstone slip. Sometimes an oilstone turned on edge will prove suitable.

Sharpening bits

Twist and centre bits

(1) Hold the bit vertically with the point on a piece of wood and file the top edge of the router at an angle of 30°.

(2) Place the bit in a vice and file the underside of the router to an angle of about 10° with the horizontal.

(3) Lightly file the *insides* of the spurs.

(4) Put a finish to the cutting edges with an oilstone slip.

Note: Never sharpen the outside of the spur and take care not to damage the threaded point.

On bull-nosed and gimlet bits use a rat-tail file, filing towards the point.

Care of oilstones

Care taken with oilstones has the three following objects in view:

(1) To retain original life and sharpness of grit,

(2) To keep the surface flat and even,

(3) To prevent the surface of the stone from glazing.

Oilstones should be kept moist and clean in a box with a cover and after use a few drops of fresh clean oil should be left on the surface of the stone.

To prevent the surface of the stone wearing unevenly tools should be sharpened over the whole surface of the stone. A worn surface may be restored by grinding on the side of a grindstone or by rubbing with an emery brick.

The use of the proper oil or water prevents a stone from glazing. Oil or water is used to float away the particles of steel from the tool being sharpened, thus preventing them from filling the spaces between the crystals and causing the stone to glaze. To prevent further glazing dirty oil should be wiped off the stone after it has been used. A dirty oilstone may be cleaned with petrol or ammonia to restore its cutting qualities.

CARE OF TOOLS

It is important to keep tools sharpened and in good condition all the time. Good workmanship is impossible with blunt, badly sharpened tools or tools with broken handles.

Slipshod or careless use of sharp tools can result in serious accidents, and methods which promote safety should be adopted at all times.

Cutting edges lose their keenness when they are in contact with metal and so care must be exercised when handling, packing, or transporting tools.

Any timber that has soil, sand, or concrete adhering to it should be brushed or scraped before any keen edged tool is used on it.

When tools are being packed away, plane irons should be withdrawn from the cutting position, the cutting edges of chisels and saws should be kept away from other metal tools, and bits should be in a roll, or other container, and not kept loose.

At all times tools must be kept free of moisture, and from time to time rubbed over with light machine oil to prevent rust.

Portable power tools

With the growing trends towards mechanisation in the building industry ,portable power tools are being used to an increasing extent.

Automatic hammer (*Fig.* 37)

The automatic hammer is an electrically operated tool which is now used, particularly on concrete jobs, for plugging and chiselling concrete.

Construction pistol (*Fig.* 38)

The construction pistol is a recently introduced tool using a gunpowder charge to drive pins or studs into concrete, steel, or brickwork for the securing of timber, joinery, and steelwork, etc. The strength of the powder charge used in each case depends upon the type of pin or stud and the material to which a fixing is to be made. The many kinds of fixings used in the

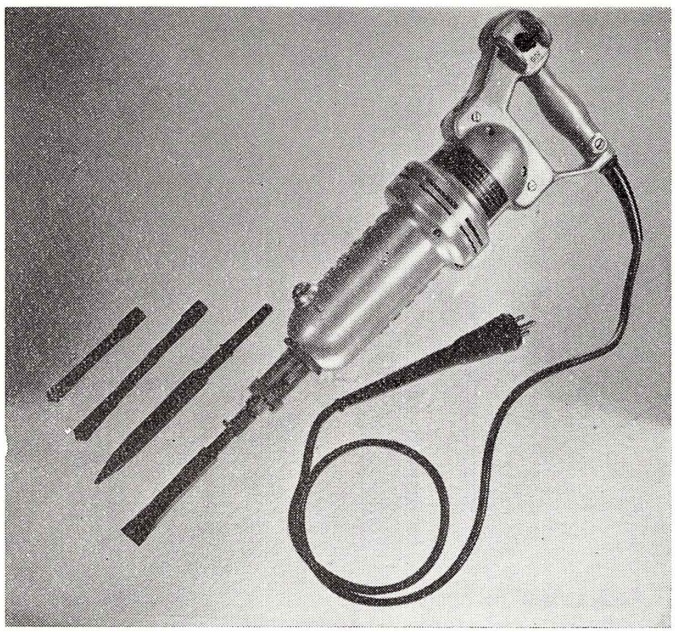


Fig. 37

Automatic hammer and accessories

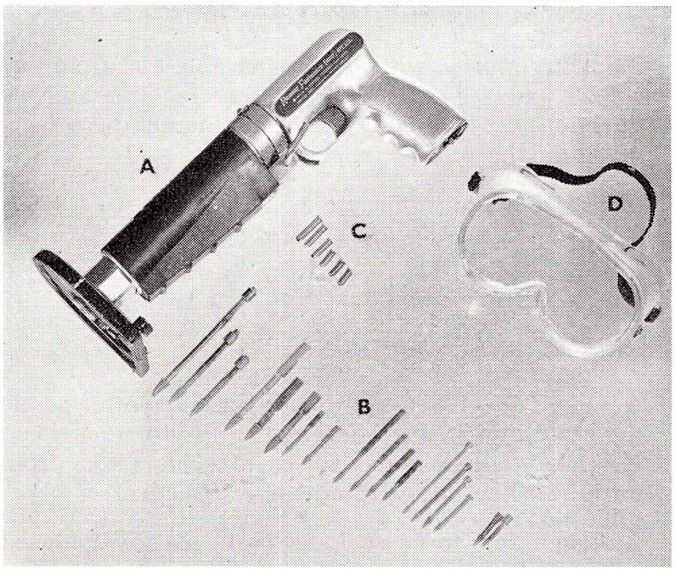


Fig. 38

Construction pistol

(A) *Pistol*
(B) *Fixings*
(C) *Explosive charges*
(D) *Goggles*

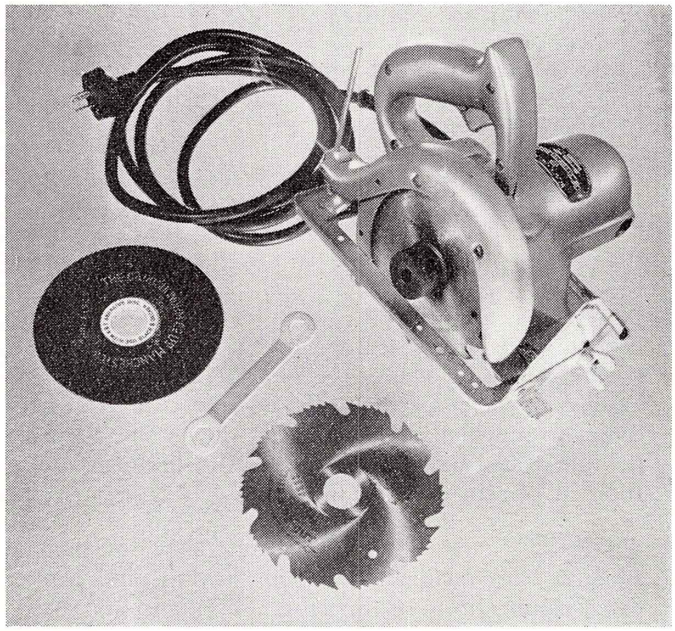


Fig. 39

Portable electric hand saw

construction pistol include hardened pins and internal and external threaded studs of various kinds. The person using the pistol must have a licence to operate it and wear the protective goggles shown.

Electric hand saws (*Fig.* 39)

Saws of this type are used for all general cutting processes of ripping and cross cutting. The saw illustrated has a tilting base for making bevelled cuts and is operated by a trigger switch. The depth of the cut is adjustable and the saw is guarded by an automatic, retractable guard, which returns into the saw housing as the machine is fed into the wood. The types of saws for use with this machine are shown in *Fig.* 39.

Electric drill

Portable electric drills of various sizes, capacities, and speeds are used by the carpenter with various drills and accessories for a wide range of boring and drilling work.

Lubrication and care of portable power tools

(1) Lubricate parts only in accordance with makers' instructions.

(2) Keep the appliance clean, dry, and in good order.

(3) Make sure that the electrical leads and plugs are in a safe condition at all times.

(4) Check all tools and leads daily before use.

Electric power connections on building sites

When a builder requires a supply of electric power on a job the following procedure is adopted.

(1) An application is made to the local electrical supply authority for a permit to install a temporary switchboard.

(2) When the permit has been granted a registered electrician fixes the switchboard on a pole near where the power will be used. All switchboard plug bases and metal components are earthed to a high-pressure water-supply pipe, if available, or to an earthing pipe driven into the ground. A weatherproof box is arranged around the switchboard.

(3) When the installation complies with the requirements of the electric power supply authority, its inspector gives permission for the power to be connected to the switchboard.

Insulation and protection of flexible leads

A flexible lead usually consists of three or more separate insulated conductors. Each conductor may contain 23, 40, 70 or more strands of fine flexible copper wire, depending upon the current to be carried. Each complete conductor is insulated with either rubber or plastic.

The appropriate number of conductors are then enclosed in a sheath of either tough rubber or tough plastic to form a round flexible lead.

Voltages and leads required

Portable electric hand tools are usually supplied at 230 volts and require a flexible lead with a minimum of three conductors.

Heavier types of tools may require 400 volts and require a minimum of four conductors.

All flexible leads should be fitted with appropriate plugs and connectors.

A useful length of lead for working within close range of the source of energy is 15 ft. to 20 ft.; to this lead extensions may conveniently be added if necessary. This arrangement tends to cut down the wear on flexible leads and also improves the performance of tools in certain circumstances.

All leads should be inspected regularly for damage such as bare insulation, broken strands, and broken earth connections. Connectors to extensions should be kept in a safe condition and clear of damp or wet areas of the building site.

Warning

The pins of any plug should never be bent or twisted in an endeavour to make them fit into a plug base. A standard type of plug should fit into its matching plug base without undue force.

Earthing of appliances

It is most important that the metal parts of all portable electric tools, used in dry situations indoors have a connection to earth.
The metal cases of electric motors, switches, and portable electric handsaws, sanders, etc. are connected to earth by a wire in the flexible lead, one end of which is connected to the metal of the machine and the other to the earth connection on the switchboard.

Safeguards

"Earthing" by means of an ordinary 3-core flex must not be used with any portable electric appliance in any outdoor situation or in any wet or damp situation within a building.

In all such situations certain approved safeguards must be adopted. The Regulations specify a number of safeguards; for general purposes the use of either an isolating transformer or a monitored earth circuit is most satisfactory.

Isolating Transformers

These transformers isolate the portable tool from any connection with "earth" in the electrical sense and the operator is protected from shock should there be a defect in the tool.

They are suitable for use with 230 volt tools with 3-core flexible leads and 3 pin plugs.

Monitored earth-circuit breakers

Another type of "safeguard" using a different principle for protection is the monitored earth circuit breaker. It is essentially a switch which prevents a tool from working when the earth circuit is defective.

Although this form of "safeguard" may be plugged into a wall or switch-board socket the circuit breaker is not in itself entirely portable as it is essential that it be mounted vertically.

It requires, for a 230 volt tool, a four wire flexible lead to the tool and a four pin plug and socket fitted to the circuit breaker. For the operation of a 400 volt tool a five wire flexible lead is needed with the appropriate plug and socket.

Safety precautions

When using portable electric power tools and machines:

(1) Do not attempt to use or repair electrical machines if an electrical fault is obvious or suspected. If you get a slight shock from any piece of equipment, suspect the whole thing, and do not use the machine until repairs have been effected and a test made by an electrician.

(2) Do not *attempt* to insert a three-pin, *230-volt, single-phase* plug into a three-pin *400-volt three-phase* base or connector.
Note: If the correct plugs and bases for the supply are used it is not possible to make an incorrect and dangerous connection.

(3) Do not wire up a three-pin plug, an adaptor or a cord extension socket unless you know the correct way of doing this.

(4) Do not pull out three-pin plugs or connectors by taking hold of the leads, as the wires are likely to be disconnected from their terminals; always hold the plug itself.

(5) Do not leave flexible leads in places where they are likely to be damaged or run over by heavy vehicles.

(6) Do not handle damaged plug-tops or connectors or appliance leads that do not appear to be in a safe condition.

(7) It is essential that fuses be reloaded with fuse wire of the correct rating.

Summary

All electrical tools and their flexible leads, plug-tops, and connectors should be maintained in good order at all times.

Aid and resuscitation

A shock from electrical equipment may be slight or severe. In some cases the person who has received the shock will be unconscious and still in contact with the electric power supply. Do not make skin contact with him until the power supply has been disconnected; otherwise you will receive a shock as well. Switch off the equipment at its own switch, at the main, or pull the lead from the socket. If the power cannot be disconnected protect yourself adequately before attempting rescue operations by using a *dry* sack, coat, or *dry* piece of timber to break the contact or move the patient. If the patient is unconscious begin artificial respiration immediately and send for a doctor without delay.

Note. If you are not familiar with the recognised methods of resuscitation for electrical shock you should prepare yourself for such an emergency by taking a course of instruction; for example, at either Red Cross or St. John Ambulance centres.

Accidents with machines

The greatest cause of accidents with machines is the human element. Such factors as human error, inattention, fatigue, lack of training and care are all liable to be the cause of serious injury.

Hardware

Metalwork and ironmongery used by a carpenter are known as builders' hardware and may be chromium plated or finely finished items of iron or steel, or may be rough hardware of the various kinds of bolts, unfinished screws, nails, straps, and hangers.
Hardware may be classified as:

(1) Fastening materials such as nails, screws, bolts, and nuts.

(2) Furnishing materials such as door locks, catches, hinges, window fasteners, and joinery trim generally. These will be dealt with in the section of the work on exterior and interior trim.

Fastening materials

Nails, screws, and bolts

Nails

Nails are of various materials, shapes, and sizes, depending upon the purpose for which they are to be used, i.e., to fasten wood and other building materials to wood. Most nails used by the carpenter are made from wire and consequently are known as wire nails. They are bright and smooth (which facilitates driving), and the shank of each nail is barbed or roughened near the head so that it will hold securely in the timber. As the length of a nail increases so usually does the diameter. Nails of a particular length may often be obtained in several gauges. The commoner types of nails are listed as follows:

Rose-head nails

Rose-head nails are used for most general purposes; galvanised forms are best for exterior work.

Brad nails

A brad nail is one with a small head, flat on the top, and available in sizes from $\frac{1}{2}$ in. to 3 in.

Flat-head nails

For nailing radiata pine timber, flat-head nails have greater holding power than rose-head nails because of the resistance of the flat head.

Galvanised flat-head nails of various lengths and size of head are used for fixing wall-lining materials, etc.

Panel pins

Panel pins are thin wire nails used for fixing plywood, mitres, etc., and are used where heavier gauge nails would split the wood, and because the small head leaves a small hole.

Clout nails

Clouts have large flat heads and are used for securing thin sheet metal, building paper, bituminous felt, and other such materials to wood. The type of clout used to secure mineral fibre cement sheets has a blunt point so that the nail punches its way through, thus reducing the risk of fracturing the cement sheet.

Roofing nails

(1) Lead-headed nails.

(2) Spring-head nails.

(3) Duralumin nails.

The above types of nails are used for nailing corrugated metal roofing materials.

Lead-head nails

These nails have a large head of lead fixed on either a flat or a rose-head nail. They can be obtained galvanised, or in bright steel in sizes of $2\frac{1}{2}$ in. and 3 in.

Spring-head nails

These nails have a cone-shaped head and are made of galvanised steel to prevent rusting.

Duralumin nails

Duralumin nails are made of an aluminium alloy known as duralumin, which is harder than aluminium. These nails are of the same shape as the spring-head nail and have a loose cone-shaped washer fitting under the head. They are used for fixing sheets of corrugated aluminium. Duralumin nails are also made in the shapes and sizes of ordinary nails but have the disadvantage that they cannot pierce hard timbers.

Corrugated fasteners (wriggle nails)

These fasteners are used for fastening woodwork joints, particularly edge-to-edge joints in boards. The fastener is tapered and draws the joint together as the fastener is driven.

Tack

A tack is a small stamped or cut nail tapered in its shank with a sharp point and a flat head.

Table 1 gives the number of nails per pound for various lengths and gauges of nails.

Table 1

Number of Rose-head Nails per lb.

Gauge	Length in Inches											
	6	5	4	$3\frac{1}{2}$	3	$2\frac{1}{2}$	$2\frac{1}{4}$	2	$1\frac{3}{4}$	$1\frac{1}{2}$	$1\frac{1}{4}$	1	$\frac{3}{4}$
4	14												
5		20											
6		24											
7			35										
8			42	49									
9					69								
10					88								
11						127	145						
12								198					
13								250	287	336			
14								330	377	442	510		
15										557	642	809	
16												1010	1305

Nails commonly used are as follows:

Framing	4 in., 7 gauge
	3 in., 10 gauge
Flooring	$2\frac{1}{4}$ in., 11 gauge floor brads
Weatherboarding	$2\frac{1}{2}$ in., 11 gauge or 3 in., 10 gauge

Ordering nails

Nails are usually sold by weight. An order should state: (1) length; (2) gauge; (3) type,
e.g., $2\frac{1}{2}$ in. x 12 rose-head.

Table 2 shows the gauge sizes of panel pins, brads, and clouts available in New Zealand.

Boring for nails

Most soft timber may be nailed without splitting unless the nails are near the end of the piece, in which case it is advisable to bore for the nails. Hardwoods can seldom be nailed without boring, and consequently a hole slightly less than the diameter of the nail is bored, to prevent the bending of the nail or the splitting of the wood.

As the ordinary pointed nail is driven, the point acts as a wedge and separates the fibres, but if the point of the nail is hammered or blunted, the nail on being driven breaks its way through the wood fibres and there is less likelihood of a split occurring.

Nails are more easily withdrawn by using a waste piece of timber under the claw of the hammer as a fulcrum.

Holding power of nails

When a nail is driven into a piece of wood the pres-

Table 2

Panel Pins and Brads							Clouts	
Length in Inches	Gauge						Length in Inches	Gauge
2	14	15					$1\frac{1}{2}$	12
$1\frac{3}{4}$	14	15					$1\frac{1}{4}$	12
$1\frac{1}{2}$			17				1	12
$1\frac{1}{4}$			17				$\frac{3}{4}$	12
1				18	19			
$\frac{3}{4}$						20		
$\frac{5}{8}$						20		
$\frac{1}{2}$						20		

sure of the wood fibres against the nail holds it and prevents the nail being easily withdrawn. Nails do not hold so firmly when driven into the end grain of timber. Nails have greater holding power when driven obliquely (known as skew nailing).

Nails that are longer than the two pieces of timber being joined are clinched by bending down the points of the nails along the grain of the timber. The point of the nail is driven with a punch into the timber, thus drawing the bent part of the nail flush with the surface of the wood.

As mentioned previously flat-head nails have greater holding power than rose-head nails, as the heads are less likely to pull through the timber.

Wood screws (*Fig.* 40)

Wood screws are made of mild steel or brass, and may be obtained in the following finishes: bright, galvanised, copper plated, nickel plated, chromium plated, and japanned.

The parts of a screw are named as follows:

Head – Most screws have a slotted head to take the blade of a screwdriver. The shape of the head gives the screw its name.

Shank – The shank is beneath the head and about two-thirds of its length is threaded to a point.

Thread–This is the prominent spiral part of a screw, which draws the screw into the wood, and provides the screw with holding power.

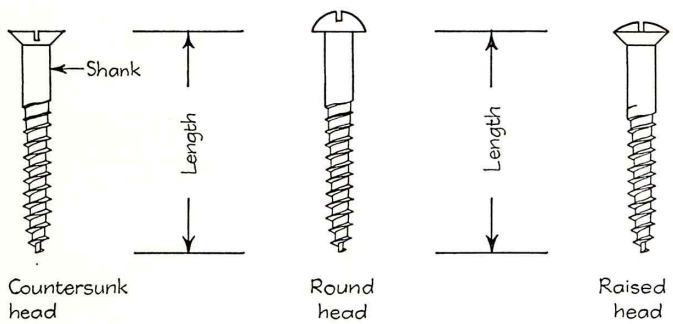


Fig. 40

Types of wood screw

Varieties and uses

(1) Countersunk or flat head. The common countersunk screw is used for general screwing purposes where the head of the screw is to finish flush with the surface of the work.

(2) Round head. These screws are flat underneath a rounded head and are used for securing pieces of timber together and fixing metal fittings. The head of the screw serves as an ornament.

(3) Raised or oval head. As shown in *Fig.* 40 this screw is really a combination of a countersunk and round head screw but is much stronger than the round head. It is used for securing metal fittings to wood and with a countersunk washer under the head for securing panels, mouldings, etc.

Gauge and length of a screw

The size of screws is designated by the length in inches and the gauge number which denotes the diameter of the shank of the screw. Thus a 1 in. No. 8 screw is a screw 1 in. long and 0·164 in. in diameter. The gauge numbers range from 000 to 32 and the length from $\frac{3}{16}$ in. to 7 in. and a range of gauges is available in each length. A simple rule to determine the gauge of a screw is to measure the diameter of the head in thirty-seconds of an inch; then take 2 from this number, and the result is the gauge. Thus a screw has a gauge of 9 if the diameter of its head is $\frac{11}{32}$ in. Screws are sold by number and are generally packed in gross packets. When ordering state:

(1) length; (2) gauge number; (3) kind of metal and finish; (4) shape of head and finish.

e.g., Screws – $1\frac{1}{2}$ in. x 10 brass, chromium plated, round heads.

Boring for screws

In softwoods it is necessary to bore a hole only for the threaded part, or core, of the screw. If necessary countersink the hole, and then lightly tap the screw with a hammer and turn with a screwdriver.

In hardwoods bore a hole for the core and for the shank, and countersink if required.

When joining two pieces of wood together with a screw, a hole must be bored in the top piece slightly larger than the shank of the screw; otherwise it is almost impossible to draw the two pieces together. Countersink if it is necessary. In the lower piece a hole is bored to the size of the core of the screw.

Holding power of screws

Because the threads of a screw cut into the timber as it is turned, the holding power of a screw is very much greater than that of a nail.

The holding power of a screw is lessened when it is driven with a hammer because a hole is made equal in diameter to the thread of the screw. A screw is turned until the head is just seated, and if over-driven it will be found that the thread has fractured the fibres and thus reduced the holding power of the screw. Brass screws easily break off and it is often advisable to first drive a steel screw of the same size before finally screwing in the brass screw. Screws should be greased for easy turning, to prevent rust, and to enable them to be removed easily, except where grease will affect the finish of surrounding wood. Soap or paraffin wax may be recommended in such a case.

Screws used in redwood must be galvanised because

of an acid in the timber that destroys the unprotected steel.

Slots of screws

The slots of screws should not be burred and when screwing on fittings, etc., all the slots of screws should point in the same direction, usually parallel with the grain of the wood.

Gimlet-pointed coach screws (*Fig.* 41A)

A coach screw is a heavy-duty screw with a square or hexagonal head, so that it may be turned by a wrench or a spanner.

The diameter of a coach screw is the diameter of the shank immediately under the head, and the length is measured from the point to the under-side of the head.

Coach screws are used for attaching metal to timber, where the ordinary range of wood screws is too small, and a bolt is not practical or necessary. The sizes range from $\frac{1}{4}$ in. to $\frac{3}{4}$ in. in diameter and from $1\frac{1}{2}$ in. up to 9 in. in length. It is necessary to bore holes for coach screws as for ordinary screws. See *Fig.* 41B, 41C.

Coach bolt (*Fig.* 41D)

Coach bolts have a rounded head under which is a square neck to prevent the bolt turning. A washer is used with this type of bolt under a square-shaped nut. When ordering bolts, the thickness of the nut and washer must be added to the thickness of the material to be bolted together. Unless the work has to be taken apart again, the end of the thread may be burred to lock the nut.

Coach bolts are available with diameters ranging from $\frac{3}{16}$ in. to 1 in. and with lengths from $\frac{3}{4}$ in. in the smaller sizes to a maximum length of 24 in.

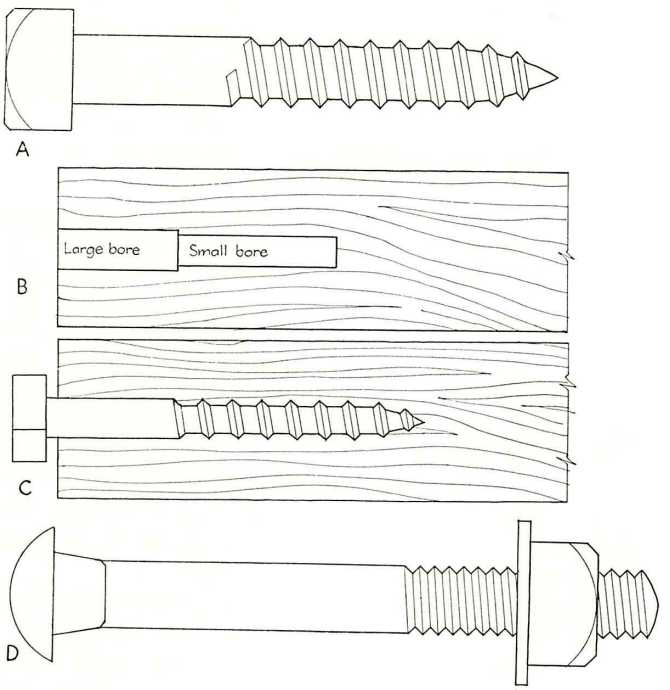


Fig. 41

(A) *Coach screw*
(B & C) *Method of boring for a coach screw and screw nearly in its place*
(D) *Coach bolt*

Questions on Chapter 1

(1) Hand woodworking tools are classified into four groups according to the purpose for which they are used. Make a list of the tools in each group.

(2) Explain how you would use a rule to divide a board into:
(a) Two equal parts.
(b) Three equal parts.

(3) How would you test the accuracy of a spirit level on horizontal and vertical surfaces?

(4) (a) At what angle are most plane irons inclined to the sole of the plane?
(b) What is the purpose of a back iron?
(c) Explain the cutting action of a plane:
(i) With a back iron.
(ii) Without a back iron.

(5) Show by sketches the cutting edge of:
(a) German jack plane iron.
(b) Smoothing plane iron.
(c) Firmer chisel.
Give the grinding and sharpening angles in each case.

(6) Name any three kinds of chisel and state the purpose for which each is used.

(7) Describe what is meant by the "set" on a saw and state whether the same amount of set is equally suitable for sawing wet and also dry timber.

(8) How would you sharpen a very blunt saw that has uneven teeth?

(9) Sketch a side view of the teeth and mark the angles of the teeth in each case.
(a) A rip saw.
(b) Hand cross-cut saw.

(10) Why is it necessary:
(a) To cool the edge of a tool when the edge is being reground on an emery wheel?
(b) To use oil on an oilstone when sharpening a plane iron?

(11) What is an oilstone slip and for what is it used? What would you recommend to keep an oilstone in good condition?

(12) With sketches describe how you would sharpen a cabinet scraper.

(13) What would you do if you found a fellow worker unconscious and in contact with an electric wire?

Calculations

(1) Find the change out of £11 when the following items are paid for: 26 in. cross-cut saw, 38s. 11d.; 16 oz. claw hammer, 33s. 4d.; ratchet brace, 37s. 5d.; combination square, 18s. 7d.; and two planes, one at 35s. 9d. and the other at 43s. 11d.

(2) A carpenter buys a set of tools for £17 1s. and pays £2 12s. deposit and 8s. 6d. weekly. How many weeks would it take to pay off the tools?

(3) A ladder has 21 rungs which are spaced at 1 ft. 3 in. centres. Find the distances between the first and the last rung.

(4) A builder purchased 35 lb. of 3 in. nails at a cost of £4 15s. 6d. per hundredweight. Find the cost to the nearest penny.

(5) Find the cost of $4\frac{1}{2}$ dozen tower bolts at 18s. 9d. per dozen.

Chapter 2

BUILDING PRELIMINARIES—PLANS AND PERMITS

Working drawings

By means of drawings and specifications an architect conveys to the contractor and eventualty to all concerned his requirements for the construction of a building. A carpenter must therefore know how drawings are prepared so that he may correctly read and interpret them. In addition such knowledge will be of value when he prepares small sets of drawings for his own use.

The architect first prepares preliminary drawings and specifications to satisfy the owner's requirements, and when the details of design have been decided upon, working drawings are prepared for:

(a) The local authority for the purpose of granting a building permit.

(b) The principal contractor, sub-contractors, and tradesmen engaged on the construction of the proposed building. These drawings include:

(1) Foundation plan.
(2) Ground-floor plan.
(3) Roof plan.
(4) Elevations and cross sections.
(5) Drawings of details.
(6) Drainage plan.
(7) Locality plan.

Plans and elevations

To represent length, breadth, and height of a building on paper at least two drawings are required, one called the plan, to show length and breadth, and the other called the elevation, to show height.

The plan is the view seen when looking vertically downwards, the eye being exactly above each point of the object in turn.

The elevation is the view of one side of a building when looking at it from the outside, the eye being in turn on the same horizontal plane as each point of the building.

Sections

Plans and elevations of buildings do not always supply sufficient information about the arrangement of the inside parts of foundation, floors, walls, roofs, etc. Imagine a building cut through by either a horizontal or vertical plane and that portion of the building between the observer and section plane removed revealing the interior construction. This view is known as a section. The cutting plane need not be continuous but may be staggered to include as much information as possible. Part sections of walls are at times drawn to a large scale to show details. The section shown in *Fig.* 49 is a view of a vertical section through the building on the reference line marked on the ground floor plan.

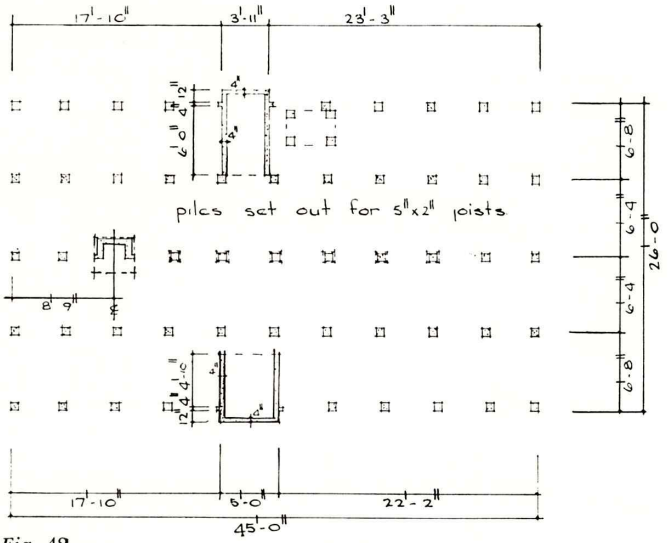


Fig. 42 *Foundation plan*

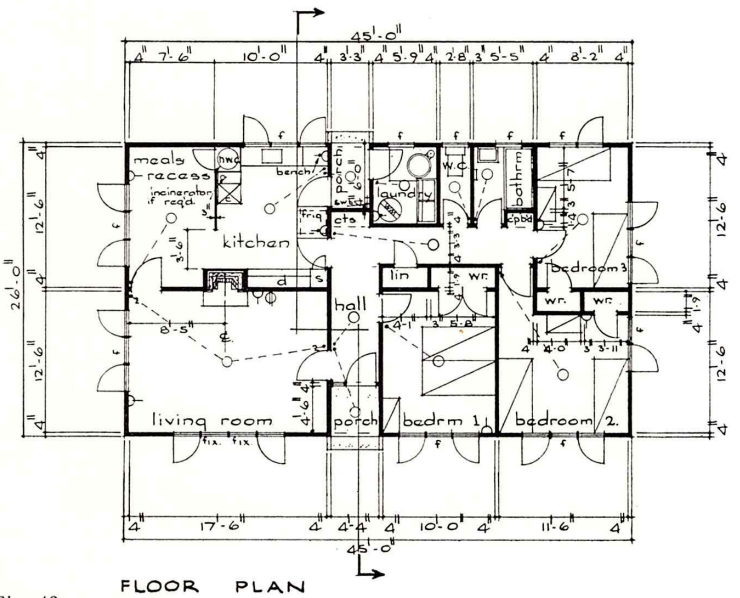


Fig. 43 FLOOR PLAN

The foundation plan (*Fig.* 42)

The foundation plan shows the sizes and spacings of piles, walls, etc. It is a view of the building cut by a horizontal plane just below the top of the foundation walls. Such a plan is usually drawn to a scale of $\frac{1}{8}$ in. to 1 ft. In all plans, it is advisable to use figured dimensions in preference to scale measurements.

Floor plan (*Fig.* 43)

The floor plan shows the building cut by a horizontal plane just above the sill of the highest window.

Roof plan (*Fig.* 44)

The roof plan shows the design of the particular kind of roof to be used on the building. Either the pitch or the slope of the roof is stated.

Elevations (*Figs.* 45–49)

Each elevation is described by the direction it faces, such as north, south, east, or west, or by front, side, or back.

Detail drawings (*Figs.* 50, 51)

Detail drawings show methods of construction to be followed in carpentry, joinery, or other work. These drawings may be either full size or to any particular scale but are usually of such size that small details may be clearly shown.

Drainage plan

The drainage plan shows the proposed layout of the sewage and stormwater disposal systems about the building and to the sewer or other outfall. The depth of the drains below ground and grades of drains must also be shown.

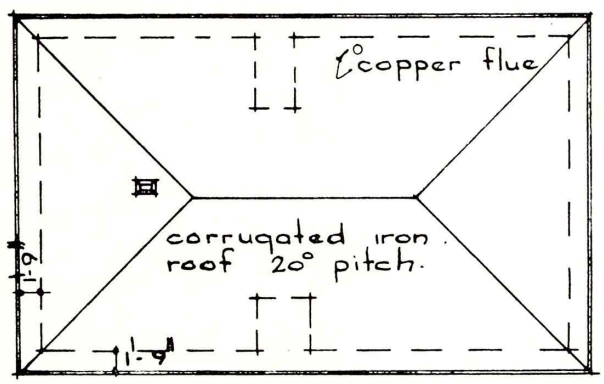


Fig. 44 *Roof plan*

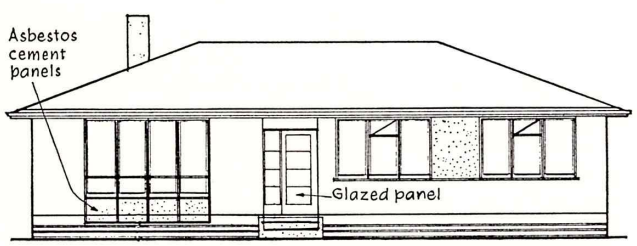


Fig. 45 *Front (north) elevation*

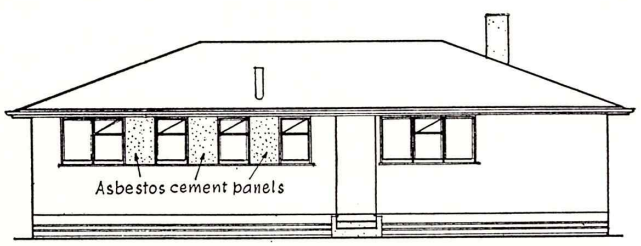


Fig. 46 *Rear (south) elevation*

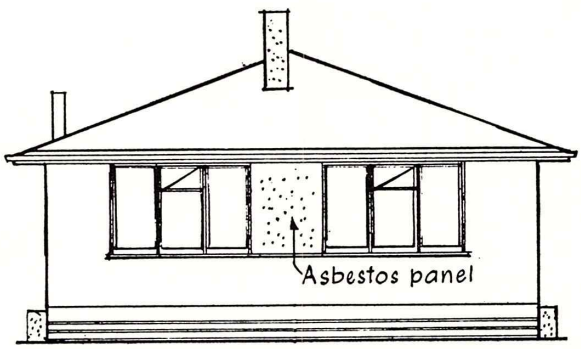


Fig. 47 *End (east) elevation*

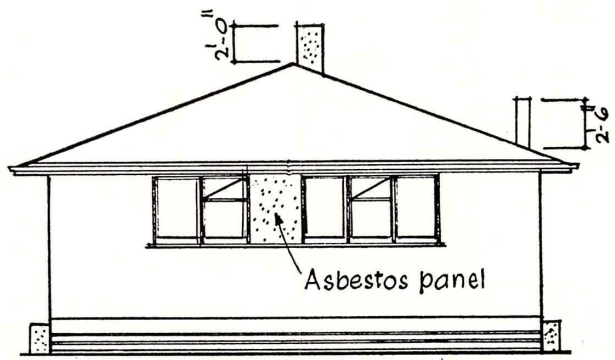


Fig. 48 *End (west) elevation*

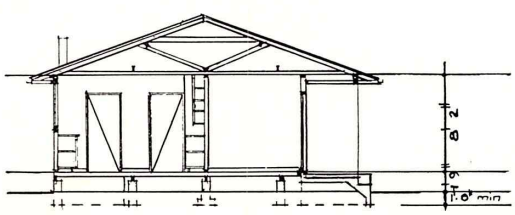


Fig. 49 *Sectional elevation*

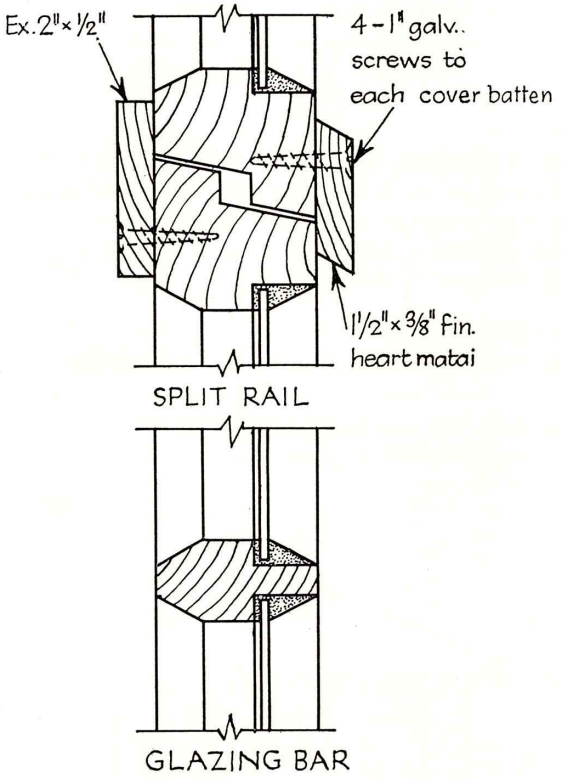


Fig. 50
Typical joinery detail showing section of split rail and glazing bar

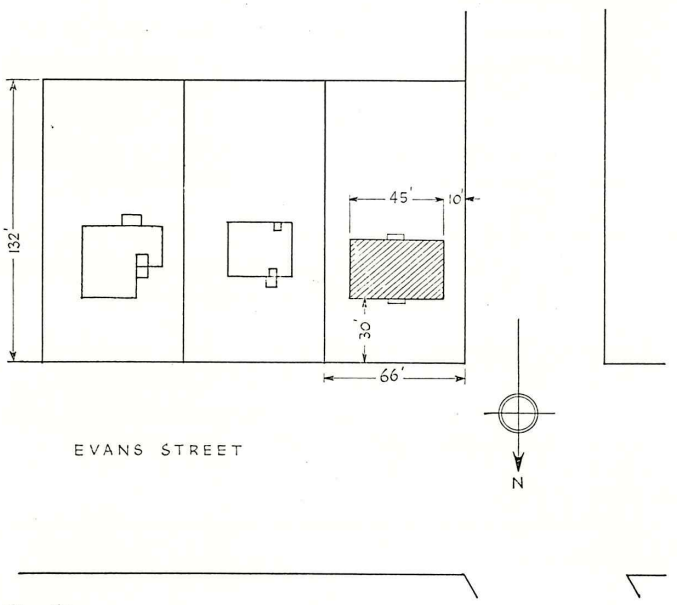


Fig. 52
Typical locality plan

Locality plan (*Fig.* 52)

A locality plan is usually to a scale of about 40 ft. to 1 in. and shows the proposed site of the building in relation to the boundaries of adjacent properties and streets.

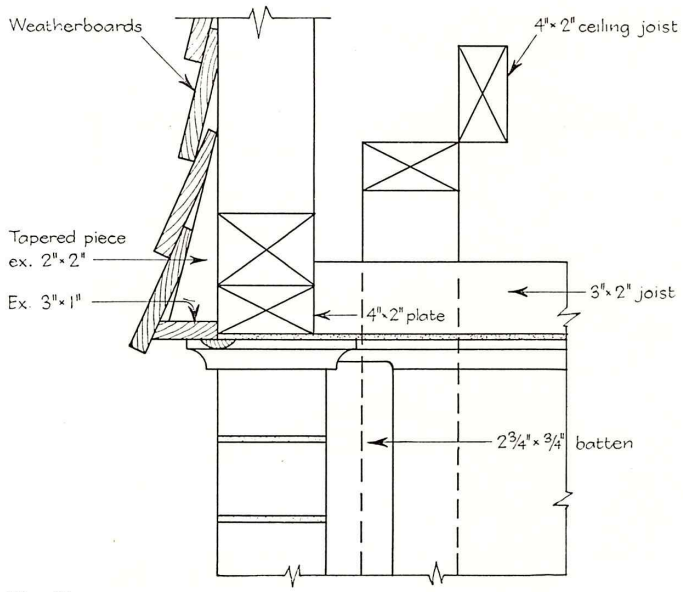


Fig. 51

Typical carpentry detail showing section through Gable wall and Entrance Porch

Specifications

A specification is a simple yet detailed description of the construction of a proposed building and must be read in conjunction with the drawings of the building. It should also contain the particulars of contract between the owner of the proposed building, the builder, and the architect.

The language of a specification should be simple, brief, and quite clear as to intent and meaning. Should measurements or details in the plans and specifications conflict, the matter must be referred to the architect whose decision is final.

Building permit

Before a builder may commence building operations he must have a building permit issued by the local authority (city, borough, or county council) in the district where he intends building.

Information of the following nature must be supplied to the local authority concerned:

(1) Name and address of applicant and also name and address of person for whom the work is to be done.

(2) Legal description of the site.

(3) The proposed use or occupancy of every part of the building, e.g., flats – residential purposes.

(4) Information as to the nature of the ground upon which the building is to be placed.

(5) Estimated cost of proposed building.

Together with an application there must be supplied for examination by the engineer of the local authority, duplicate copies of detailed plans, elevations, cross sections, and specification which together should furnish complete details of design, qualities, and description of all materials of construction and workmanship. After payment of a fee, based on the value of the proposed building, a permit to build is granted if the drawings and specification comply in all respects with the local authority's bylaws relating to building, drainage, plumbing, etc. On the other hand the engineer may require further information, or alterations to be made to the drawings and specifications so that they will comply with the bylaws.

Detailed information on the procedure for obtaining a building permit is given in N.Z.S.S.* 1900, Chapter 2.

Design of dwellings

To design a house that combines both attractiveness and utility many points must be considered. The amount of money available and the family to be catered for will govern the size, design, and finish of the house. On a sloping site the costs of building will be greater than those of a building on a comparatively level section. An ideal site would have the following features. It would:

(1) Receive a reasonable amount of sun.

(2) Have a good topsoil and a free-draining subsoil (for a garden).

(3) Not be low-lying but have sufficient fall for a workable sewage and stormwater drainage system.

(4) Not be so steep as to make building difficult and costly.

(5) Have protection from prevailing winds.

(6) Have an interesting view.

(7) Have available such services as water supply, drainage, lighting, and heating, refuse collection, and communal deliveries.

Arrangement of house on section

Every room in a house should if possible have sun at some time of the day. To do this the corners of the house should point to the cardinal points of the compass, i.e., north, south, east, west (*Fig.* 53 A, B).
On small sections and with streets running in diverse directions the above ideal siting of a house is not always possible.

Plan arrangement

The arrangement of rooms in a house will be determined partly by the site and aspect but a good plan will be simple and compact and should provide a maximum amount of comfort and convenience for the money and space available.
Some methods of achieving this ideal are:

(1) Bedrooms should be grouped around the bathroom.

(2) Easy access from the kitchen to the dining room and living room should be available.

(3) The kitchen, laundry, and bathroom should be close so that leads for hot water and drainage are short.

(4) Doors in general, when opened, should hide the rooms.

(5) Fireplaces should be placed as far away as possible from windows and doors but not in a corner. The centre of a long wall is a good position.

(6) Passages should be as short as practicable and not run direct from the front to the back door.

(7) Sun should shine in the right rooms at the right times of the day. Climate and latitude play a big part in deciding this matter. Some people prefer the early morning sun in the bedrooms and later in the living rooms, while others like the kitchen and living room to get the first sun and the sitting rooms and bedrooms to receive the afternoon sun. In general it may be stated that in New Zealand as much use as possible should be made of the heating and lighting effects of the sun.

Other important points include:

(i) A pleasing exterior appearance of the house.

(ii) An economical overall plan designed to give the best features for the money and space available.

* New Zealand Standards Specifications published by the New Zealand Standards Institute.

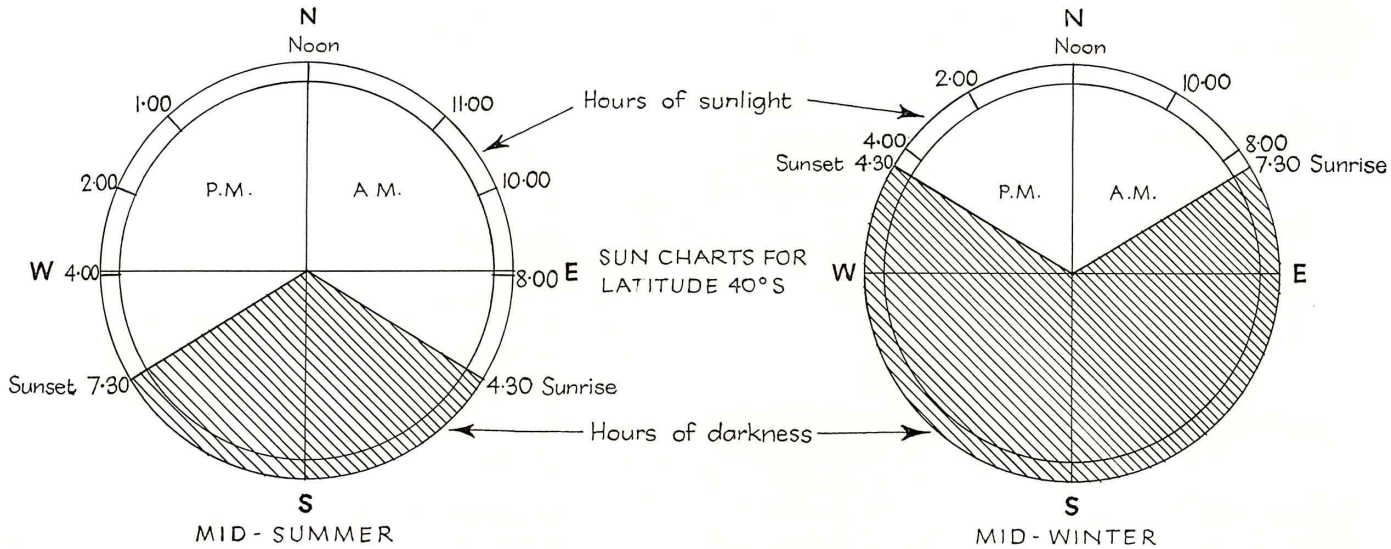


Fig. 53A

Siting a house

Preparation of drawings

Original drawings

For original drawings a good quality drawing paper that will withstand the use of an eraser is recommended. The drawings are first done in pencil and then inked in with indian ink.

Tracing

When copies from original drawings are required they should be made on semi-transparent tracing paper or tracing cloth. The surface of the paper should be unglazed so that firm dense lines may be easily drawn. Sheet plastic tracing fabrics are occasionally used instead of the usual tracing materials.

In copying, the quality of the reproduction will depend upon the transparency of the paper or cloth and the firmness and density of the lines, whether in ink or in pencil.

Larger sheets of tracing paper and particularly tracing cloth should be stretched and pinned on the drawing board for a period before use in order to reduce the tendency to distortion after the work on the sheet has commenced. It is also desirable, for the same reason, to try to complete the tracing of any one view before leaving the tracing overnight.

Tracing cloth after stretching should be treated with finely powdered chalk applied with a clean soft cloth. This removes any greasiness and helps the drawing of even dense ink lines.

Reproduction of drawings

White lines on blue ground (Blueprints)

A tracing is made from an original drawing in either ink or pencil on white or bluish-tinged tracing paper or cloth. The tracing is then placed in a printing frame with a sensitised printing paper. After exposure the print is washed in running water, when white lines on a blue background are produced. This method is known as the ferro-prussiate process.

Reflex copying

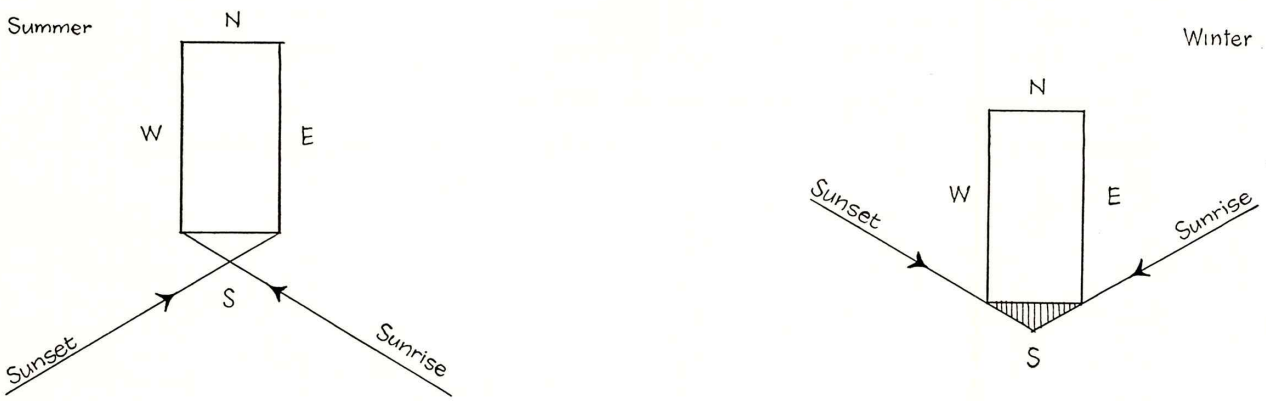
Reflex copying is used for plans with printing or writing on one or both sides of the paper. The sensitive reflex paper is used to make a negative copy, from which as many copies as are required are printed by the ordinary contact method.
Modern practice employs sensitised papers designed to give black, blue, purple, or sepia lines on a white background, but ferro-prussiate papers giving white lines on a blue base are still in popular use because such a print is more legible when soiled than a white print.

Modern methods of reproduction of drawings

Within recent years industry has made use of a process of non-optical photography whereby the characters on a plan or document are transferred from the original to a sheet of light-sensitive paper, thus avoiding the tracing of drawings. There are many processes by which copies of drawings, plans, and sketches may be obtained rapidly and cheaply.

IDEAL SITING OF SQUARE HOUSE

IDEAL SITING OF RECTANGULAR HOUSE



SITE HOUSE SO THE SHORTEST WALL IS SUNLESS IN WINTER

POOR SITING - LONGEST WALL IS SUNLESS IN WINTER

Fig. 53B *Siting a house*

Typical building application form:

BUILDING APPLICATION FORM

DATE.....19.....

To the.....Engineer,

Sir,

I hereby apply for permission to..... at *(House No. and street)*.....

for *(Owner)*..... *(Address)*..... according to locality plan and detailed plans, elevations, cross sections, and specifications of building deposited herewith, in duplicate.

Particulars of land: Lot No..... D.P..... *On Town Section* .....

Length of boundaries:..... Area:.....

Particulars of building—Foundations:..... Walls:.....

Roof:.....

Area of ground floor:.....square feet.

Area of outbuildings:.....square feet.

Estimated cost—

Building .... £.....

Plumbing and drainage .... £.....

Total .... £.....

Proposed purposes for which every part of building is to be used or occupied (describing separately each part intended for use or occupation for a separate purpose):.....

Proposed use or occupancy of other part of building .....

Nature of ground on which building is to be placed and of the subjacent strata:.....

Yours faithfully,

.....Owner

.....Builder.

Postal Address:.....

Typical permit form:

FORM OF PERMIT

.....Council.—Building Permit.

No..... ..... Engineer's Office, ..., 19.....

To Mr..... (Occupation), (Address).

In pursuance of your application for permit to..... permission is hereby granted you to carry out the work as proposed in your application, and in accordance with the plans, particulars, and other documents submitted to me, such work to be subject at any time during progress to my inspection, and to be carried out in strict conformity with all requirements of the ..... Bylaw..... 19....., and all other bylaws of the city for the time being in force and of all Acts of Parliament and regulations respectively affecting such work.

....*Engineer.*

Questions on Chapter 2

(1) A house of two bedrooms, lounge, kitchen, etc. is to be built on a narrow (40 ft.) section which is at right angles to, and on the south side of a road running east and west. Draw a line diagram showing how you would locate the house on this section to take advantage of the most sunlight available.

(2) "A permit to build" must be granted by a local authority before a building may be erected. What are the usual formalities required to obtain a permit?

(3) If you intended buying a section and building a house for yourself describe the desirable features you would seek when buying the section and also state how you would plan the house and site it on the section.

(4) What are "plans" and "specifications"?
In the case of any inconsistency between the plans and specifications who would make a final decision?

(5) Name and describe one process of making twenty copies of a plan.

Calculations

(1) A building was estimated to cost £2,800 and finally cost £3,210. What is the percentage increase on the original estimated cost?

(2) The owners of three sections with frontages of 40 ft., 50 ft., and 60 ft. propose to share the cost of new road-formation work in proportion to the width of their sections. If the cost of the work is £550 per chain, what would each owner pay?

(3) A roading authority has decided to improve visibility at the intersection of two streets by cutting the corner off a section to a distance of 25 ft. down each street.
   (a) How many square yards of land would the section owner lose?
   (b) What is the cost of fencing across the corner at £10 per chain?

(4) A house of 1,063 sq. ft. is situated on a section with a frontage of 50 ft. and a depth of 110 ft. If 300 sq. ft. is allowed for concrete paths, how much land is left for garden and lawns?

(5) A dwelling of 1,075 sq. ft. cost £3,015 to erect. What was the cost of building per sq. ft. of floor area?

Chapter 3

TIMBER

Classification of trees

There are two groups of trees that produce building timbers, namely, *hardwoods* and *softwoods.*

These terms are based on botanical distinctions relating mainly to the flowers and not to the actual hardness or softness of the wood.

In New Zealand we have native trees of both groups. Hardwoods have flowers and seeds of the same general structure as the flowers and seeds of most garden plants. Hardwoods can be more readily distinguished, because most of them have broad-shaped leaves; hence the name "broad leaved trees". (*Fig.* 54.)

Softwoods belong to the order *Coniferales* and many of them bear cones and have needle-shaped leaves. The only cone-bearing tree native to New Zealand is the kauri, the other native softwoods bearing fleshy seeds.

Fig. 54 shows a twig of taraire, a New Zealand hardwood, and *Fig.* 55, a twig of rimu (softwood).

New Zealand forests are known as rain forests and may be divided into two main classes::

(1) The sub-tropical forest or rain forest proper.

(2) The sub-Antarctic forest or beech forest.

The former is a mixed community of hardwoods and softwoods and the latter is often dominated by one or more of the species of beech. For practical purposes the names "rain forest" and "beech forest" are sufficient. Between these two classes there are intermediate divisions which merge into the two main groups.

Though the forest-tree species of New Zealand number about 112, only a few are of value as timber trees; in fact, at present only 9 are being used to any extent by sawmillers, and of these, 6 are softwood timbers.

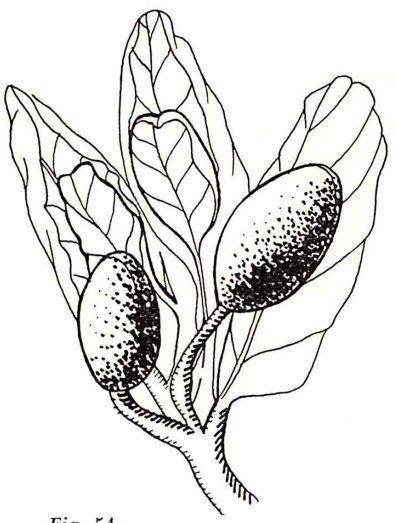


Fig. 54
Sprig of taraire
(hardwood type of tree)

The growth of trees

In the spring when the warm rains fall, water soaks into the ground and dissolves some of the mineral salts. This solution is absorbed by the root hairs (fine thread-like extensions of the roots) and passes up to the leaves through the passages in the sapwood. This solution of minerals contains all the elements necessary for the vital growing processes of the tree, with the exception of carbon, which must be obtained from the air.

The gas carbon dioxide, together with the other gases of which air is composed, passes into the leaves through the stomata, which are minute openings found chiefly on their under surfaces. The green colouring matter (chlorophyll) enables the living substance of the plant in the presence of light, to split up carbon dioxide into its elements carbon and oxygen, and to use the carbon in building up food substances – sugar and starch. As this building-up process (synthesis) takes place only in the presence of light (Greek – photos), it is termed photosynthesis. The food thus built up can be stored as starch (which is insoluble) and can later be changed to sugar (which is soluble) for transport to all parts of the plant (*Fig.* 56).

From the leaves the food materials pass down the *phloem,* that is, the inner bark, to the cambium layer. This is the active layer of the tree where new wood cells are formed by the repeated division of the cambium cells, some of which go to the inside of the layer to form new wood and some to the outside to extend the bark.

Fig. 55
Sprig of rimu
(softwood type of tree)

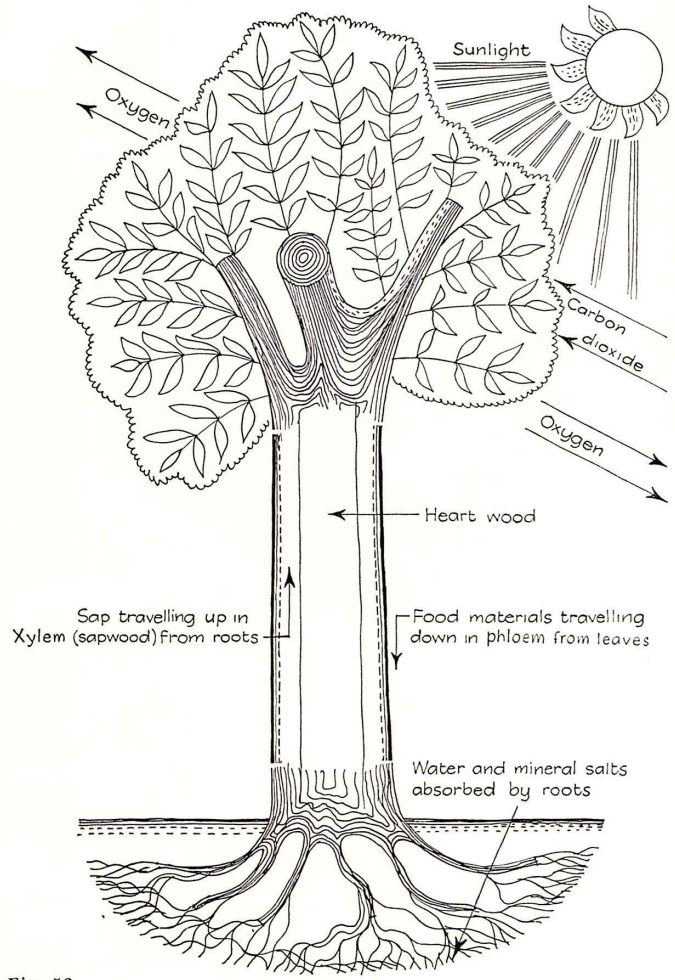


Fig. 56

Diagram showing growth process of a tree

Cross Section of Tree Trunks

In *Fig.* 57 are shown cross or transverse sections through typical hardwood and softwood tree trunks. The most important features are labelled and briefly described below.

(A) Is the outer bark or corky layer composed of dry dead tissue; it gives general protection to the tree against external injury.

(B) Is the soft inner bark, or phloem, which carries food prepared in the leaves to the cambium layer.

(C) Is the cambium layer just inside the inner bark. This is the active growing layer of the tree where new wood cells are formed.

(D) Is the light-coloured sapwood or *xylem,* which carries the sap from the roots to the leaves.

(E) Is the heartwood or fully matured wood. It is darker in colour than the sapwood and is formed by a gradual change in the sapwood. It is inactive, its main function being to provide strength to support the trunk and branches.

(F) Is the pith which is the remains of the soft tissue about which the first wood growth took place.

(G) Are the medullary rays (commonly known as wood rays) which connect the various layers from pith to cambium for storing and transferring food.

Types of Cells

Softwoods

The principal cells found in the wood of softwoods are *tracheids* and *medullary rays.* Some of these cells enclose ducts called *resin canals* (*Fig.* 58).

Tracheids

The great bulk of cells in the wood are tracheids each with its long axis along the grain. These cells are arranged very evenly and combine the work of conducting the sap (in sapwood) and providing strength. During spring growth tracheids are large but during summer and autumn growth they are flattened and their walls are considerably thicker.

Medullary rays

The medullary rays found in both hardwoods and softwoods are thin-walled cells, running in a radial direction. They serve a threefold purpose of supplying the inner bark with water, the living cells of the wood with

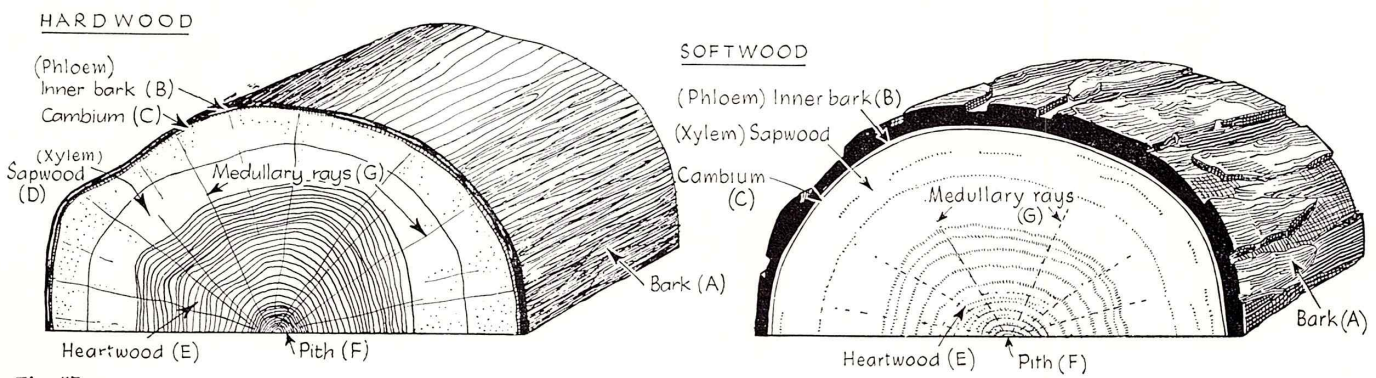


Fig. 57

Cross section of hardwood and softwood tree trunks

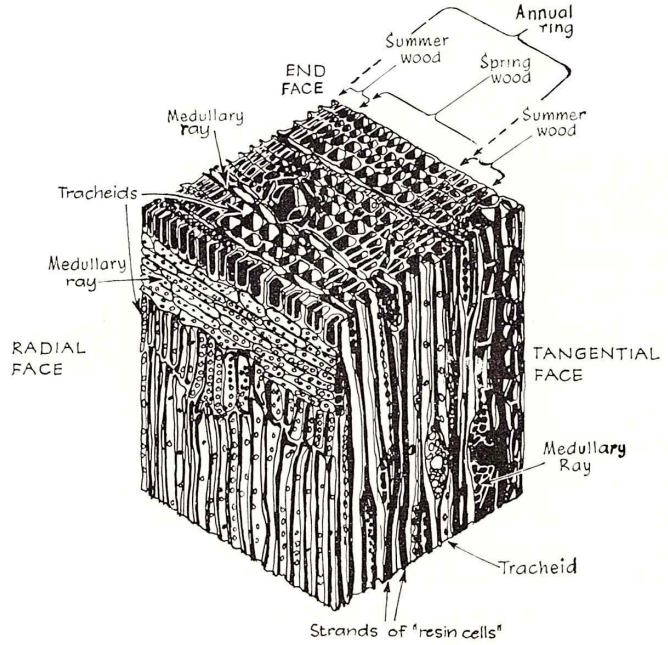


Fig. 58

Softwood structure
(representation of a cube of 1/32 in. side)

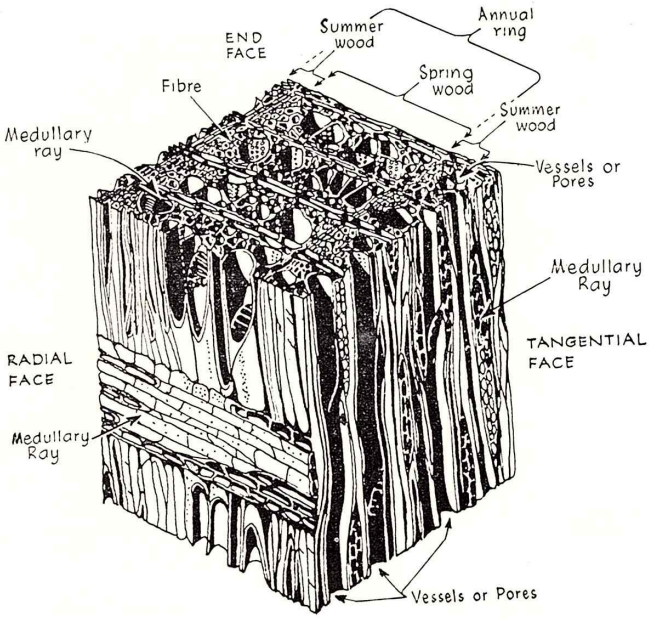


Fig. 59

Hardwood structure
(representation of a cube of 1/32 in. side)

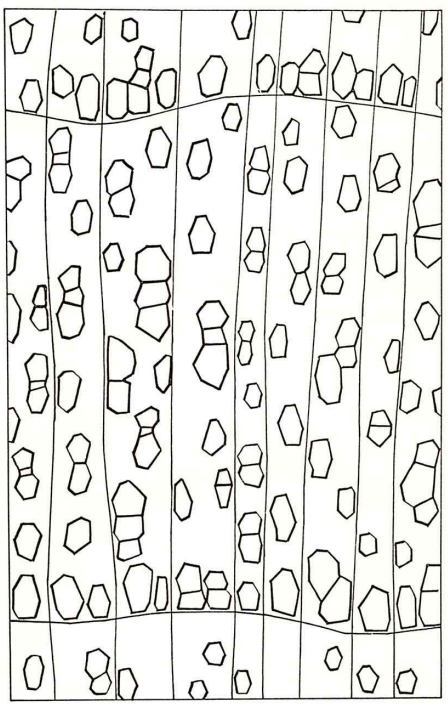


Fig. 60

Arrangement of vessels of diffuse porous hardwoods

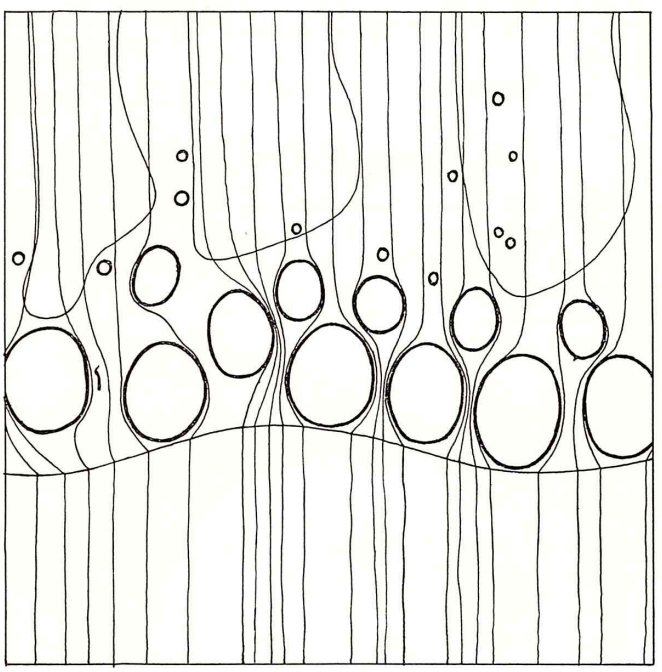


Fig. 61

Arrangement of vessels of ring porous hardwoods

the nourishment manufactured in the leaves and conveyed down the trunk by the inner bark, and as food-storage cells. A few softwoods also have scattered food-storage cells running parallel with the tracheids. In some species of softwoods the rays are almost invisible, whereas in some species of hardwoods, such as oak and rewarewa, the rays are very large and are characteristic features of the timber.

Resin canals

Resin canals are simply spaces in the wood into which the surrounding tissues secrete resin. Pines, spruce, douglas fir, and some others, have resin canals, and on the side grain of radiata pine heartwood these may be seen as fine brown lines. The cells sheathing these canals secrete resin which flows copiously whenever the tree is wounded. Native softwoods have no resin canals, the resinous material often being concentrated in the wood rays of the heartwood (e.g., kauri), but it may spread to the nearby tracheids.

Gummy heart rimu, the lustre and fleck seen in kauri, and the slow-drying of paint on totara and matai are all due to the resinous character of the wood concerned.

Hardwoods

The cells of hardwood are vessels, fibres, and medullary rays (*Fig.* 59). The medullary rays in hardwoods have the same functions as those in softwoods. Unlike the tracheids in softwoods, which conduct the sap and provide strength, the cells in hardwoods are of two distinct kinds, vessels and fibres. The vessels are thin-walled and are joined together, end to end, like drainpipes, while the fibres are thick-walled and provide strength in the tree. Hardwoods are not so fine and even-textured as softwoods. Some hardwoods have abundant food-storage cells lying parallel with and often surrounding the vessels, or forming bands alternating with bands of fibres.

Vessels vary in size during the year. If they decrease *gradually* in size from spring to summer the hardwood is *diffused porous* (*Fig.* 60). Other hardwoods are *ring porous* because the early spring vessels are large and form a distince ring and *abruptly* change in size to the smaller summer vessels (*Fig.* 61). Beech and poplar are examples of diffuse porous hardwoods while oak, ash, and elm are ring porous hardwoods. The great variety of patterns on the end grain of hardwoods, as seen under a hand lens or microscope, considerably affects the properties of the timber.

Sapwood and heartwood

As the number of annual rings in the wood increases, there comes a time when, in the trunk of many trees, the vessels and tracheids of the inner rings become filled with gums and resins. Such blocking of the water-conducting parts is usually followed by the death of all cells in the annual rings. These dead cells form what is known as *heartwood*. Water and dissolved minerals from the roots now travel upwards only in the outer, younger rings which constitute the *sapwood*. From year to year more rings on the inner part of the sapwood are changed to heartwood. Thus, the sapwood of any particular tree remains about the same thickness from year to year, whereas the heartwood is continually increasing in diameter.

Felling of trees

To obtain the best timber, trees should be felled as soon as possible after they have reached their prime. If they are cut before maturity, the timber produced is not considered to be as durable as that from a fully matured tree. On the other hand, if the tree is cut too long after maturity, the central portion may have begun to decay and the wood produced may be brittle.

Felling operations in commercial practice in New Zealand take place throughout the year.

When a tree is felled, the branches are sawn off and the trunk is cut into logs varying in length from 7 ft. to 20 ft. for the convenience of transporting to the mill.

Conversion and manufacture of timber

"Conversion of timber" is the sawing of a log into baulks, planks, scantlings, boards, etc., and includes the resawing of these timbers to exact sizes. The planing, moulding, tongueing, and grooving of such material is known as "'manufacture".

Conversion of timber

The method of sawing logs into sawn timber depends to a large extent on the machinery at the sawmill, the species of tree, the sizes of the logs being sawn, and the particular dimensions to which the timber must be sawn.

Methods of Conversion

Before dealing with the methods of breaking down a log it is necessary to understand the terms "tangential" and "radial" when applied to the sawing of a log. Tangential and radial saw cuts refer to the surface exposed by the saw cut in relation to the growth rings and medullary rays of a tree (*Fig.* 62). It will be seen that a tangent cut is one which forms a tangent with the growth rings and a radial cut one that is in the direction of the radius of the log, i.e., parallel to the medullary rays.

Flat- and quarter-sawn timber

(1) *Flat-sawn timber*

Flat-sawn timber is converted so that the growth rings meet the face in any part at an angle of *less* than 45° (*Fig.* 63A). Other names for flat-sawn timber include plain-sawn, slash-sawn and tangential-cut or -sawn.

(2) *Quarter-sawn timber*

Timber converted so that the growth rings meet the face in any part at an angle of *not less* than 45° (*Fig.* 63B). Quarter sawing is also known as radial sawing.

In the past, confusion has often arisen on account of the many names that have been applied to a particular conversion process, but the above specification, from the publication, *British Commonwealth Forest Terminology,* provides a simple standard which is easily understood.

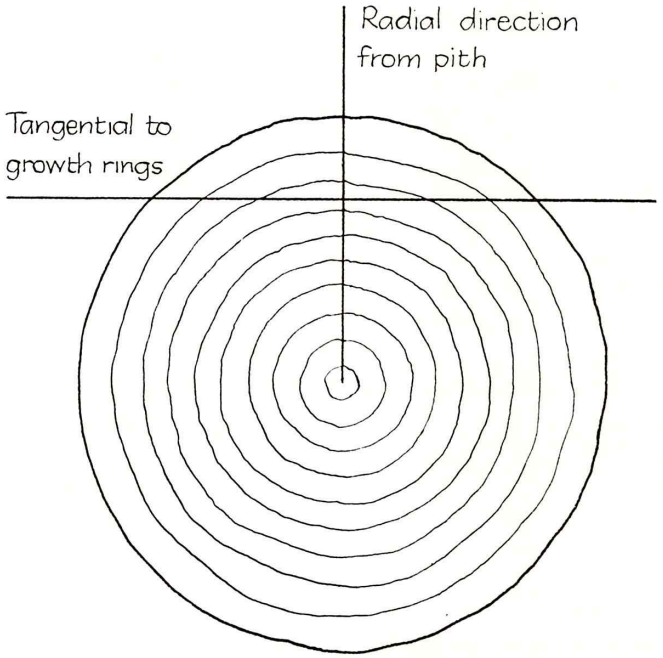


Fig. 62

Cross section of tree trunk showing the direction of saw cuts in relation to the growth rings

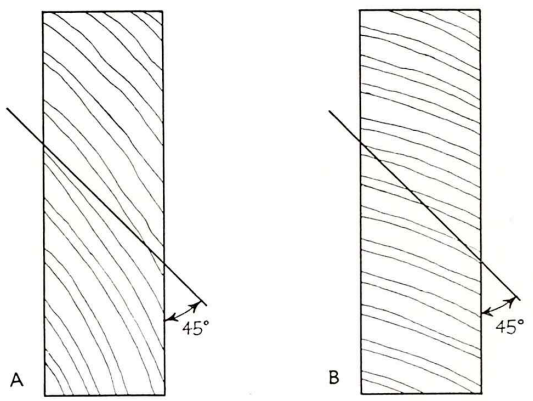
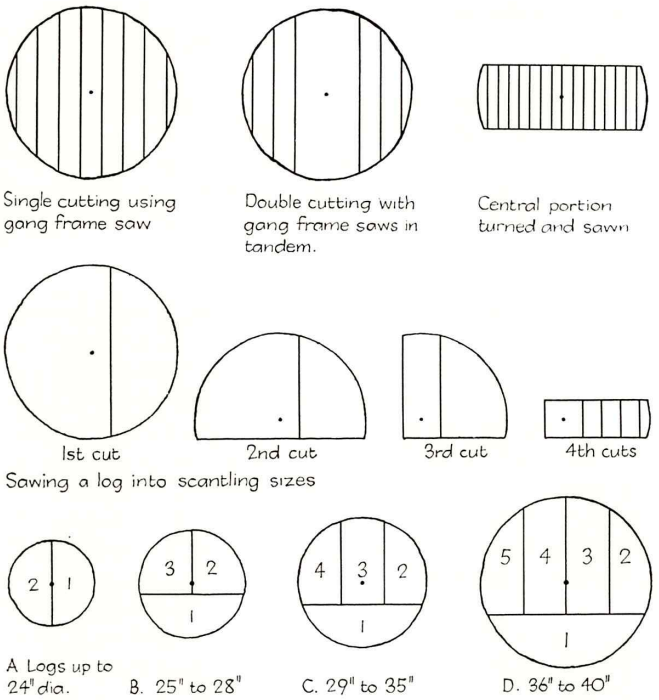

45°
A
45°
B
Growth rings meet face of board at an angle LESS than 45°
Growth rings meet face of board at an angle NOT LESS than 45°
FLAT SAWN TIMBER
QUARTER SAWN

Fig. 63

Diagrams showing the distinction between flat- and quarter-sawn timber


Single cutting using gang frame saw
Double cutting with gang frame saws in tandem.
Central portion turned and sawn
1st cut
2nd cut
3rd cut
4th cuts
Sawing a log into scantling sizes
2 1
3 2 1
4 3 2 1
5 4 3 2 1
A Logs up to 24" dia.
B. 25" to 28"
C. 29" to 35"
D. 36" to 40"

Methods of breaking down logs into flitches of various diameters with twin circular breaking down saws. The flitches are next broken down into the smaller sizes of building timbers.

Fig. 64

Methods of sawing logs of various diameters

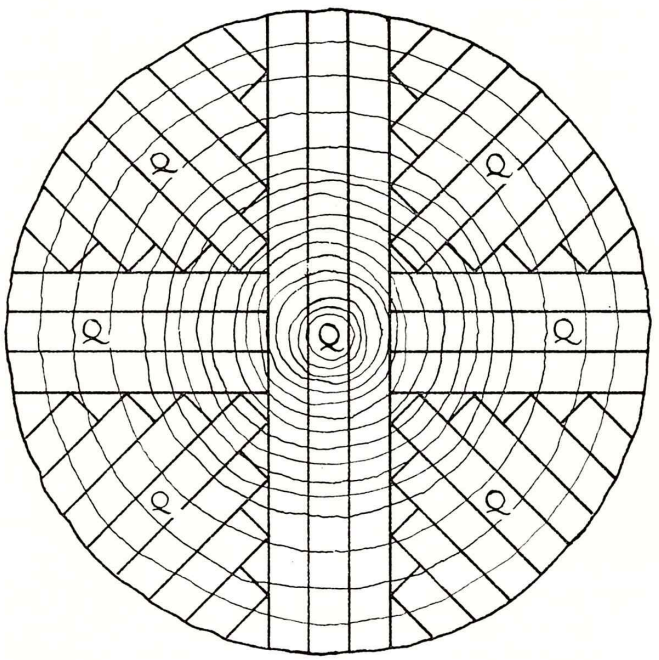


Fig. 65

Method of quarter sawing logs to obtain radial cut or fully quarter-sawn boards

Boards marked Q *are true radial cut or fully quarter-sawn boards*

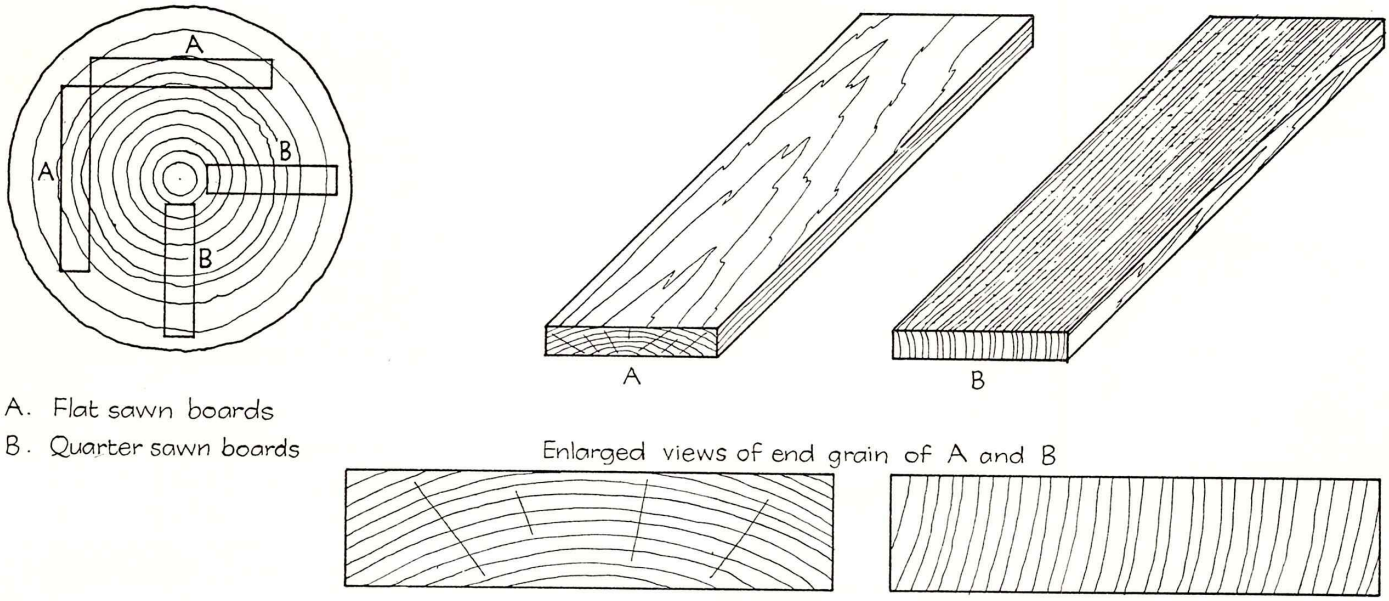


Fig. 66
Relative positions of flat- and quarter-sawn timber in a log. Note appearance and direction of end and surface grain in each case

Conversion processes

The simplest process is that of sawing a log into boards in one operation, but on the other hand a log may be sawn into quarters, or at least into the larger timber sizes and then resawn into the other sizes required. The amount of quarter-sawn timber produced depends upon the method of conversion as can be seen by studying *Fig.* 64.

Quarter sawing, in which the log is sawn by making cuts parallel with the medullary rays, as in *Fig.* 65, is rarely, if ever, carried out because the process is slow, expensive, and wasteful. Should some of these types of boards be required for a particular purpose they could be selected from flat-sawn timber, but otherwise any number would be obtained by the resawing of quarter-sawn flitches of timber. Timbers with a prominent medullary ray show the figure of the grain to best advantage when quarter sawn, and such timbers do not shrink, cup, or warp to the same extent as flat-sawn timbers.

Flat-sawn timber is satisfactory for most purposes but has the disadvantage that it tends to shrink and cup more than quarter-sawn timber.

Fig. 66 shows the relative position of flat- and quarter-sawn timber in the log, and views of end and surface grain in each case.

Timber measurement

Sawn timber is sold in New Zealand in grades as specified in the New Zealand Standard Specification 169 (N.Z.S.S. 169), Classification and Grading of New Zealand Building Timbers (National Grading Rules).

The original green, rough-sawn size (known as nominal size) of all timber classified and graded under N.Z.S.S. 169 is the basis of measurement.

Timber 1 in. and over in thickness is tallied as board measure (in ft. B.M.) and timber under 1 in. in thickness is tallied as surface measure (in square feet). Mouldings and trimmings are tallied in running, or linear, feet irrespective of the volume of timber they contain.

It should be noted that the term ft. B.M., the standard unit for the measurement and tally of building timbers, has not yet fully replaced the term "'superficial foot".

Calculation of board measure

There is one "foot board measure" in a piece of timber 1 ft. long, 12 in. wide, and 1 in. thick or in a piece of timber of equivalent volume, i.e., 144 cu. in.

As will be seen from the illustration in *Fig.* 67 the blocks of wood each contain 1 ft. board measure, although their dimensions are different.

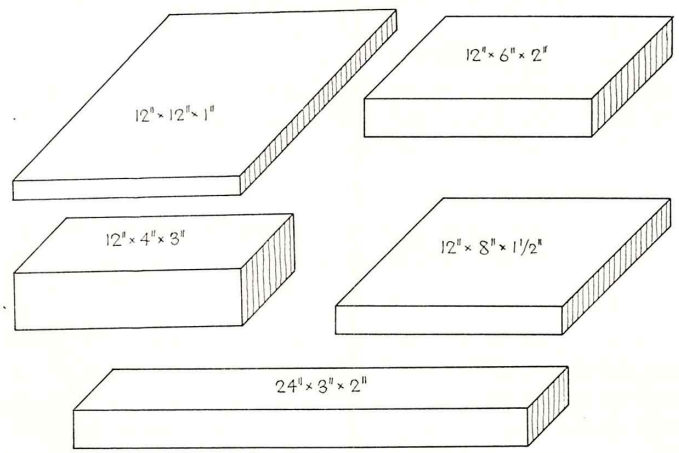


Fig. 67
Diagrams show pieces of timber of 1 ft. board measure

To find the number of feet board measure in a piece of sawn timber of any dimensions, multiply together the length in feet, the width in inches, and the thickness in inches and divide by 12.

Written as a formula:

$$\text{ft. B.M.} = \frac{L \times W \times T}{12}$$

Where L = length in feet, W = width in inches and T = thickness in inches.

Example 1. Find the number of ft. B.M. in a piece of timber 24 ft. long, 7 in. wide, and 1 in. thick.

$$\text{ft. B.M.} = \frac{L \times W \times T}{12}$$
$$= \frac{24 \times 7 \times 1}{12}$$
$$= 14 \text{ ft. B.M.}$$

Classification and grading of building timbers

The National Grading Rules (N.Z.S.S. 169) have been adopted by all major wood-producing and -using interests, covering radiata pine and the common indigenous building timbers.

Indigenous building timbers are classed in two groups of standard grades, one for framing (framing grades) and the other for finishing purposes (finishing grades).

Framing Grades	*Finishing Grades*
Building A	Clears
Building B	Dressing A
Commons	Dressing B

Radiata pine timber is classified under the following grades:

(1) Factory Grade
(2) Finishing Grade
(3) Dressing Grade
(4) Merchantable Grade
(5) No. 1 Framing
(6) No. 2 Framing

The rules describe the number and extent of the defects allowed in each grade. Every builder should have a copy of these grading rules.

Moisture in timber

The timber of living trees and freshly felled logs contains a large amount of water in the cell cavities and the cells walls. This water often weighs more than the solid (dry) timber itself, and affects the weight, strength, shrinkage, and liability to attack by some boring insects and by fungi that cause stain and decay.

Determination of moisture content

The moisture content of timber can be determined by either of the two following methods:

(1) *Moisture meter method*

The moisture meter operates by measuring the electrical resistance of timber, which increases as the timber dries. The steel points connected to the meter are forced into the timber and the meter measures the resistance to the flow of current between the two points. From this reading the moisture content may be determined.

The moisture meter method has definite limitations, for example:

(1) It is reliable only between 6% and 24% moisture content.

(2) Correction data must be used when testing different species and/or qualities of timber or when testing timbers treated with preservatives.

(2) *Oven-dry method*

The amount of moisture in timber varies but the dry weight of wood substance in any sample is constant. Therefore it is usual to express the variable (moisture content) as a percentage of the constant (dry weight) as follows:

$$\frac{\text{Initial weight of sample} - \text{dry weight of sample}}{\text{dry weight of sample}} \times 100$$

It will be seen that the moisture content of undried wood may be over 100 per cent. To say that the M.C. percentage is 120 per cent. simply means that the ratio of water to dry matter in the sample is 120 to 100, i.e., 6 to 5.

Fibre-saturation point

The cell walls of living trees are saturated with water and also the cell cavities are filled with water as a cup may be filled with water. During seasoning the water in the cell cavities is removed first without affecting the properties of the timber other than its weight, and when the moisture content is reduced to about 25 to 30 per cent. the timber is at its *"fibre saturation point"*, i.e., the remaining water is contained in the cell walls. Until this stage is reached there is little change in the shape or size of the cells, or of the whole piece of timber. Drying below F.S.P. is accompanied by loss of water from the minute structure of the walls and the wood shrinks.

Moisture content of the atmosphere

Water is constantly evaporating into the air and the amount of moisture which air can hold or retain is constantly varying with its temperature. This condition of the atmosphere, with regard to its moisture content, is known as the humidity of the air, and relative humidity is the ratio expressed as a percentage of the amount of moisture held in the air at any temperature, to that which could be held in the air at that temperature.

Air that is saturated with water vapour will have a relative humidity of 100 per cent and air with lesser amounts will have a lower relative humidity.

Hygroscopic moisture

Air-dried wood absorbs moisture from a damp atmosphere, i.e., one with a high relative humidity, and loses moisture when air has a low relative humidity, i.e., in dry air. The moisture in the cell walls received from the air is known as hygroscopic moisture.

Movement of wood

When the relative humidity of the air is high, wood absorbs moisture and swells, and at a low relative

humidity loses moisture and shrinks. The changes in the moisture content of the atmosphere cause a constant swelling and shrinking of the wood which is called "movement" or "working" of the wood. This explains why windows and doors jam during a wet or humid spell of weather and are loose and rattle during dry periods as in summer.

Shrinkage

When green wood dries below its fibre saturation point it changes its dimensions or shrinks. These changes occur in the following directions:

(1) Along the length of a log.

(2) Around the curvature of the growth rings or more correctly in a direction tangential to them, i.e., at right-angles to the medullary rays.

(3) In a radial direction, i.e., from the pith to the bark.

Wood shrinks very little in length but tangential shrinkage is about twice that of radial shrinkage as shown in the following table, which gives the percentage of radial and tangential shrinkage in the common New Zealand timbers.

Table 3

Shrinkage from "green" to 12 per cent moisture content

Timber	*Radial*	*Tangential*
Rimu	2·0	4·5
Heart miro	2·3	4·8
Sap miro	2·6	6·6
Heart matai	1·5	2·5
Sap matai	2·3	3·8
Totara	2·2	3·6

Differential shrinkage

The ratio of tangential to radial shrinkage is known as the *differential shrinkage.*

When timber dries it shrinks and alters its shape or becomes distorted. These distortions are due to the difference between radial and tangential shrinkage and vary according to the position of a piece of timber in the log as shown in *Fig.* 68. When selecting timber for a particular job advantage is often taken of the fact that quarter-sawn timber shrinks and distorts less than flat-sawn timber.

In *Fig.* 68 the original size and shape of the "green" sections are shown as a background to the distorted shapes that the sections assume on drying.

(A) A flat-sawn board is shown "cupping" away from the heart.

(B) A square section with growth rings diagonally across section dries to a diamond-shaped section.

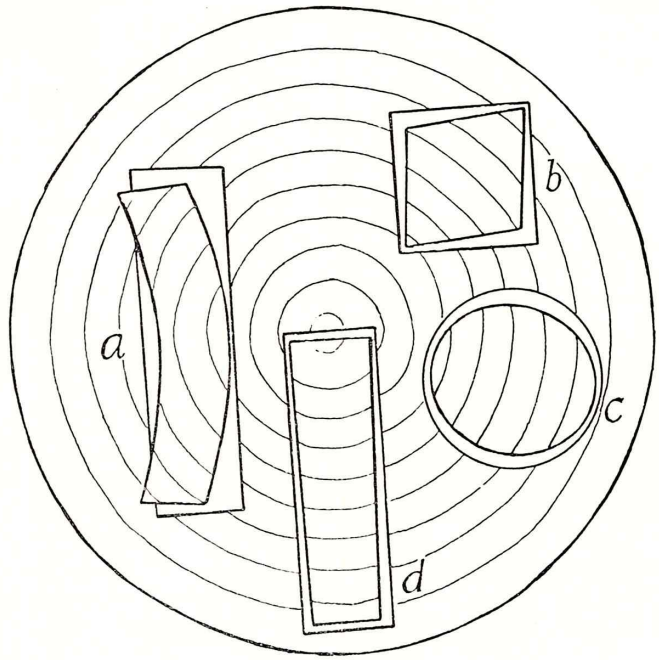


Fig. 68

Distortion resulting from the effects of radial and tangential shrinkage on various shaped pieces of timber sawn from a log

(C) A round section assumes the shape shown.

(D) A quarter-sawn section distorts very little, and shrinks relatively more in thickness than in width.

The distortions that are due to differential shrinkage are further illustrated in *Fig.* 69.

It is not easy to see how this differential shrinkage causes a board to warp or cup. To make it clear take the example of a 6 in. x 2 in. shown in *Fig.* 70. Suppose this 6 in. x 2 in. was sawn into three 2 in. x 2 in. sections. After drying, these three sections would assume the shapes shown in (B). Now, if these pieces were then joined together again, as shown at (C), they would assume the shape which is characteristic of a warped board – hollow on the sap side and round on the heart side.

Note that it is always the "sap" side which goes hollow if further drying takes place. A glance at the end grain of a board will tell you which side is likely to go hollow; and you can therefore build it into the job in such a way that future warping will do the least harm. (The heart side is usually placed on the outside or exposed side of the job.)

The middle section, (B) in *Fig.* 70, has retained, more or less, its rectangular shape. The reason for this is that the tangential rate of shrinkage has affected the width while the radial rate has affected the depth. In cases where a board is quarter-sawn the differential shrinkage does not affect the flatness of the board; such a board merely has a greater rate of shrinkage in the thickness direction than it has in width.

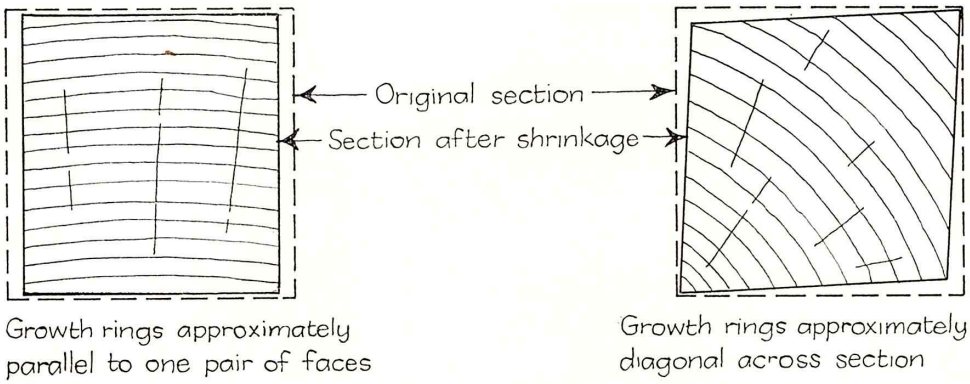

Original section
Section after shrinkage
Growth rings approximately parallel to one pair of faces
Growth rings approximately diagonal across section

Fig. 69

Effect of shrinkage on square sections of timber

Note: We have been discussing the distortion which occurs in evenly seasoned timber. This should not be confused with the excessive cupping or warping which takes place when one side of a board is dried out more than the other, as might happen before seasoning is complete, or in the top boards of an uncovered stack.

Moisture content of seasoned timber

During seasoning, drying continues until a stage is reached when there is practically no further interchange of moisture between the wood and the air. When this condition has been reached the wood is in a state of equilibrium. Subsequent changes in temperature or moisture content of the air disturb this state of equilibrium and an exchange of moisture takes place until a new state of equilibrium is reached. When atmospheric conditions are changed, as by some form of heating in a previously unheated house, the moisture equilibrium of the timbers will be upset to such an extent that a noticeable movement will occur in joinery, fittings, and furniture, and the signs of shrinkage will be most apparent.

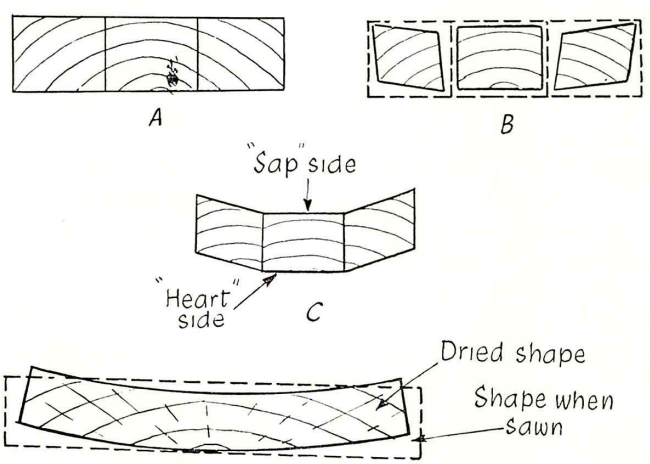


Fig. 70

Distortions which cause cupping of timber

From the above description of the causes of movement in timber it will be readily understood that movement of timber will be obviated to a large extent if it is seasoned so that its moisture content is such that the timber will neither absorb or lose moisture under the conditions existing where it is to be used. The moisture content of wood at which a stable condition occurs, when used under controlled conditions, is called its *equilibrium moisture content,* and is based on an average moisture content.

The following table gives suitable moisture contents to which timber should be dried for use:

Table 4

Recommended moisture contents for New Zealand timbers

Purpose for which timber is to be used	*Equilibrium moisture content Per Cent*
Framing and structural timbers where further drying out can occur	25
Sheathing behind stucco, sarking, weatherboards, and all exterior trim	17
Exterior joinery such as sashes and frames, gates, wooden steps, etc.	15
Interior joinery subjected to only occasional heating	14
Woodwork in normally heated situations including reasonable central heating, e.g., flooring and matchlining, cupboard fittings, and built-in furniture	12

Seasoning of timber

The objects of seasoning timber

If timber is dried to a moisture content in equilibrium with its proposed surroundings, there will be a minimum of movement. This stabilising of wood by drying is perhaps the most important result of seasoning, but at the same time there are other advantages which are not always apparent. They are as follows:

(1) Timber with a moisture content below 20 per cent is free from wood-rotting and sap-stain fungi. Seasoned timber is therefore saved from decay or spoiling from these fungi, provided, of course, that it does not pick up moisture from, say, damp conditions.

(2) Seasoned timber is the only class of timber in a fit condition to be painted or polished.

(3) If good penetration of a wood preservative is required, the timber to be treated in most cases should be seasoned timber.

(4) Seasoned timber is stronger than green timber.

(5) Seasoned timber is much less corrosive to ferrous metals than wet timber.

Principles of seasoning

The cells of the outermost layers of wood lose water by evaporation and this causes the moisture in the inner layers to move outwards. When the outer layers of the wood are dried too quickly, they are prevented from shrinking by the wetter interior and consequently become stretched. These outer layers may set in this stretched condition (known as casehardening) or the outer layers may crack, resulting in surface checking. Successful seasoning lies in maintaining a balance between the evaporation of water from the surface of the wood and the outward movement of water from the interior.

Relative humidity, the rate of circulation of the air, and its temperature are the three factors which control water movement in wood, the most important being relative humidity. The greater the relative humidity of the air surrounding the wood which is to be seasoned, the slower is the drying process of the wood. When the temperature of the air is raised, however, its relative humidity falls so that drying is accelerated. Drying is speeded up also by replacing the moist air surrounding the wood by air with a lower humidity. Thus we see that the relative humidity of the air, its temperature, and its rate of circulation about the wood must all be controlled if timber is to be seasoned satisfactorily.

Methods of seasoning

Timber will never dry to any extent in the log. It must be cut into boards before seasoning can take place.

There are two methods commonly employed, air seasoning and kiln seasoning.

Air seasoning

Air seasoning takes advantage of the drying powers of the air and the sun. The rate of air drying depends largely on the weather and in this country is not very fast. By this method timber seldom dries much below about 18 per cent moisture content.

Stacking of timber

Timber that must be stored for long periods is usually built into covered stacks (*Fig.* 71) and joinery establishments often have sheds for the storage and air seasoning of timber.

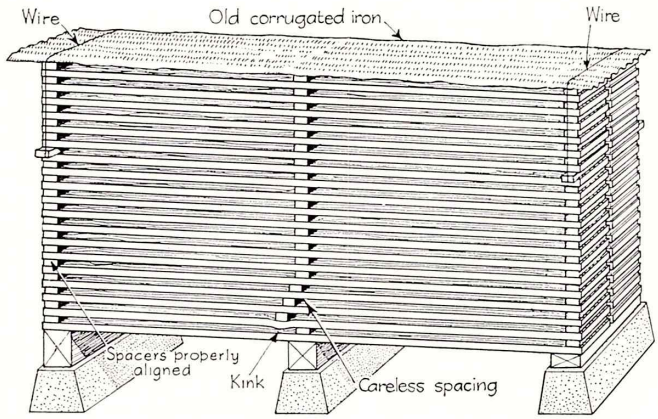


Fig. 71

Stacking of timber
Alternatively, front of larger stacks may have wider overhanging front fillets

Whether timber is to be stored in a building or in the open air the methods of stacking are much the same. The foundations of timber stacks should be placed so that the lowest boards in the stack are at least 18 in. above the ground, except where drying is very fast, and a stack in the open must have a fall of about 6 in. to every 10 ft. to shed rain.

The site under a stack should be clear of grass, sawdust or rubbish. Circulation of air through the stack is secured by separating successive layers of timber by $\frac{3}{4}$ in. or 1 in. strips of wood known as fillets and by leaving spaces to provide for vertical movement of air. One-inch boards are stacked with 1 in. fillets at 16 in. to 24 in. centres. Fillets must be placed vertically above each other and not too far apart; otherwise distortion and sagging will occur.

The following precautions should be observed in stacking timber to reduce warping:

(1) Place fillets in exact vertical alignment over solid foundation members.

(2) Use fillets of uniform thickness.

(3) Use correct spacing between fillets.

(4) Avoid variations of board thickness in any layer.

(5) Use a roof that provides protection from sun and rain.

(6) Hold down the roof on the stack by heavy weights, or pass wires over the top of the stack with the ends secured to the foundations.

(7) In drying random lengths of timber avoid, by sorting for length, unprotected and unsupported overhanging ends.

(8) To prevent timbers from splitting at the ends some protection is required, particularly if the timber is exposed to the weather for a long time. This protection may be obtained by placing the end fillets so as to overhang the ends of the boards, by fastening either wood or metal strips on the ends of the boards or by coating the ends with a waterproof substance.

Timber on the building site

As timber awaiting use on the building site will deteriorate if left lying on the ground exposed to the sun, wind, and rain, it should be arranged in stacks until it is required.

On most occasions it is necessary to stack it only for short periods and so the timber is arranged in triangular stacks on the ground (*Fig.* 72) or racked as shown in *Fig.* 73. The method of stacking timber with fillets is rarely if ever used on a building site but it is common practice in joinery works and sawmill yards.

Kiln-dried timber, joinery, or finishing timbers on a job should always be kept covered. This precaution also applies to preservatised timbers, particularly those which have been treated with a water-soluble preservative.

Degrade in air seasoning

Splitting, checking, staining, or discoloration are the most usual forms of damage resulting from air seasoning. Most softwoods are very liable to be attacked by sap-stain fungi, and if it is considered necessary, various antiseptic solutions may be used for dipping timber before seasoning.

Kiln seasoning

Kiln drying involves the use of temperatures considerably in excess ot atmospheric temperatures. Speedier drying than occurs in air seasoning is only effected because of controlled air circulation, humidity, and temperature. The higher temperatures cause the moisture in the wood to move rapidly to the surface when it is evaporated by the circulating air.

The timber is stacked with fillets between the boards, similar to those used for air seasoning, and then the stack is placed in a kiln in which temperature and humidity are controlled. By this means any predetermined moisture content may be achieved. Kiln drying, properly carried out, has no deleterious effect on the wood.

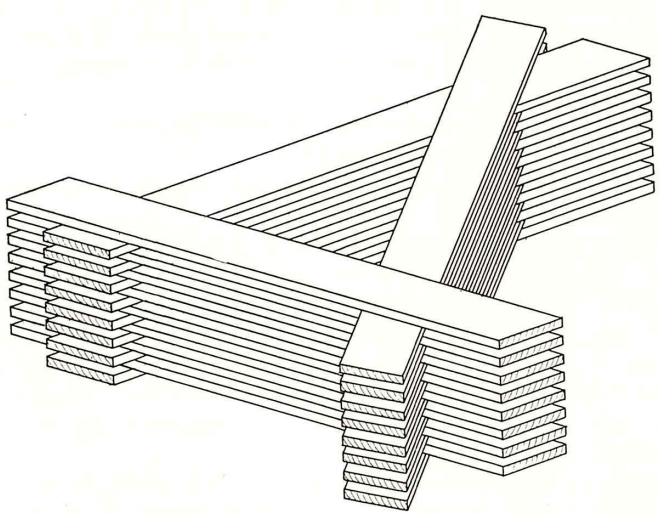


Fig. 72

Triangular stack of timber

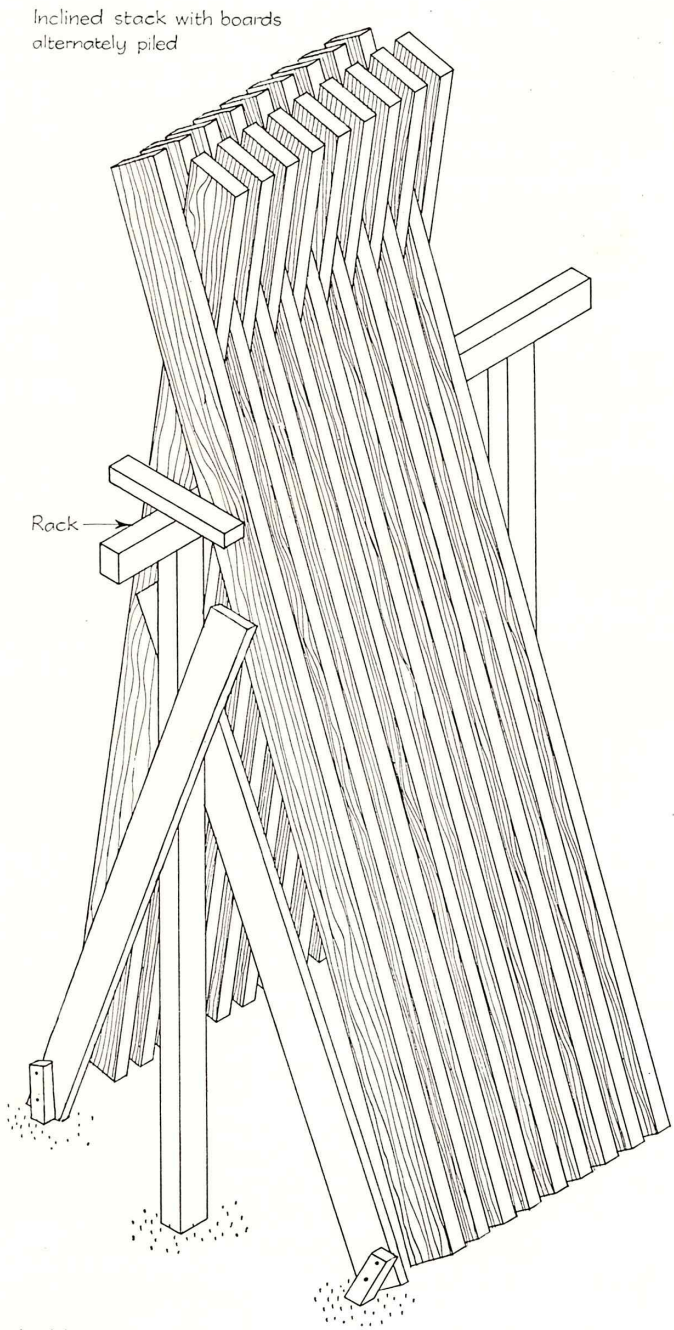


Fig. 73

Method of drying timber on racks

Advantages of kiln drying

The advantages of kiln seasoning are as follows:

(1) Speed at which timber may be seasoned. The process reduces the time required from months or even years to a few days.

(2) Timber can be dried to a predetermined moisture content to suit particular conditions.

(3) A dependable supply of seasoned timber at any season of the year is assured.

(4) In properly operated kilns, every piece of timber in a kiln load can be dried to a *uniform moisture content* throughout.

(5) The process sterilises the timber, as the temperatures used in the kiln will kill any insect or fungus present in the timber. Such sterilisation does not, of course, protect the dried timber against fresh infestation after removal from the kiln.

(6) The resins or gums in certain woods are to a large extent set or hardened in kiln drying so that the risk of subsequent bleeding from finished surfaces is reduced.

On the other hand errors in the technique of kiln operation may have serious results, and whole kiln loads of timber can be completely spoilt by improper kiln operation.

Types of kilns

(1) Kilns in which the air is circulated by making use of the natural tendency of hot air to rise and cold air to fall, are known as natural-draught kilns.

(2) Kilns in which mechanical means, e.g., fans, are employed to drive the air, are known as forced-draught kilns.

Progressive kilns

In the progressive kiln the wet timber enters at one end and gradually moves along towards the other end, the air being arranged to flow in the opposite direction to the movement of the timber, so that timber which has been longest in the kiln receives the air when it is hottest and driest.

Compartment kilns

A compartment kiln, like a progressive kiln, consists of a closed chamber but it differs in operation in that the timber remains in the same position in the kiln throughout the drying period, the temperature and humidity of the circulating air being constantly changed. The great advantage of compartment kilns is their flexibility in operation coupled with the fact that they are designed to give accurate control over drying conditions. Flexibility is desirable when the kiln loads are constantly changing both in species and dimensions of timber, and accuracy of control is essential for the successful drying of difficult timbers.

The type of kiln most widely adopted in New Zealand is the internal fan, reversible, cross-ventilation, compartment type. *Fig.* 74 shows a typical section through such a kiln and illustrates the above features.

The air is heated as it passes over the steam-heated coils; the relative humidity is controlled by the steam jets and ventilators; circulation is brought about by the power-driven fans which force the hot, moist air between the layers of timber and then expel certain quantities of it, if required, through the roof ventilators.

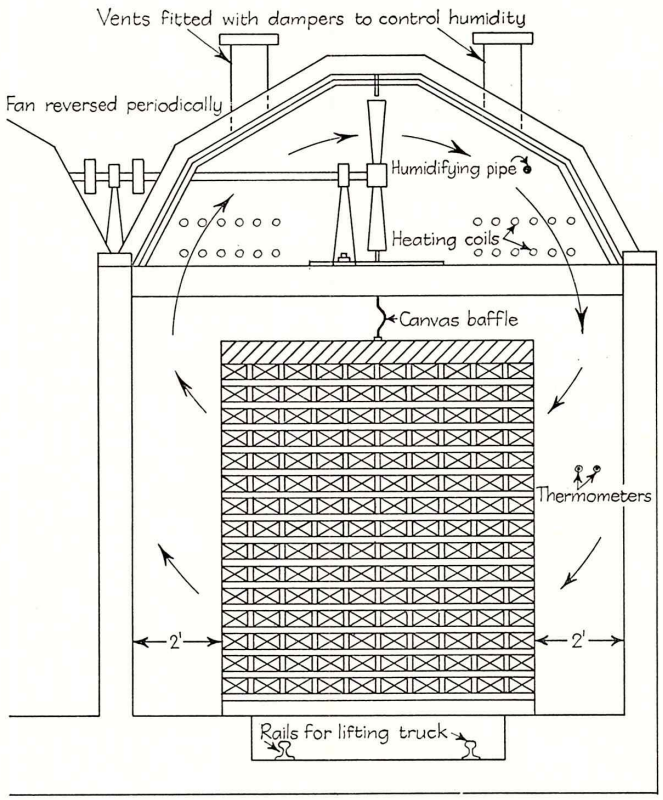


Fig. 74

Cross section of compartment kiln

Seasoning defects

It has been explained that as wood dries it shrinks, and that the shrinkage is not uniform in all directions. Moreover, the outer layers of a piece of timber tend to dry out more rapidly than the interior, resulting in temporary or permanent distortion of the timber, and even in separation or rupture of the tissues. This distortion and rupture of the tissues of timber is referred to as *seasoning degrade.*

Permanent distortion gives rise to various forms of warping, rupturing of tissues, checks, splits, and shakes as follows:

Warping is any variation from a straight line or plane surface. It includes bow, crook, cup, twist, or any combination of these (*Fig.* 75).

Bow is a deviation from a straight plane surface longitudinally and is distinct from a crook in that it applies to the broadest face of the piece. In other words bowing is the sagging of a piece of timber from end to end as a result of the wide spacing of fillets in a timber stack which allows the timber to sag under its own weight. The amount of bow is determined by measurement at the point of greater deviaton from a straight line drawn from end to end of the piece.

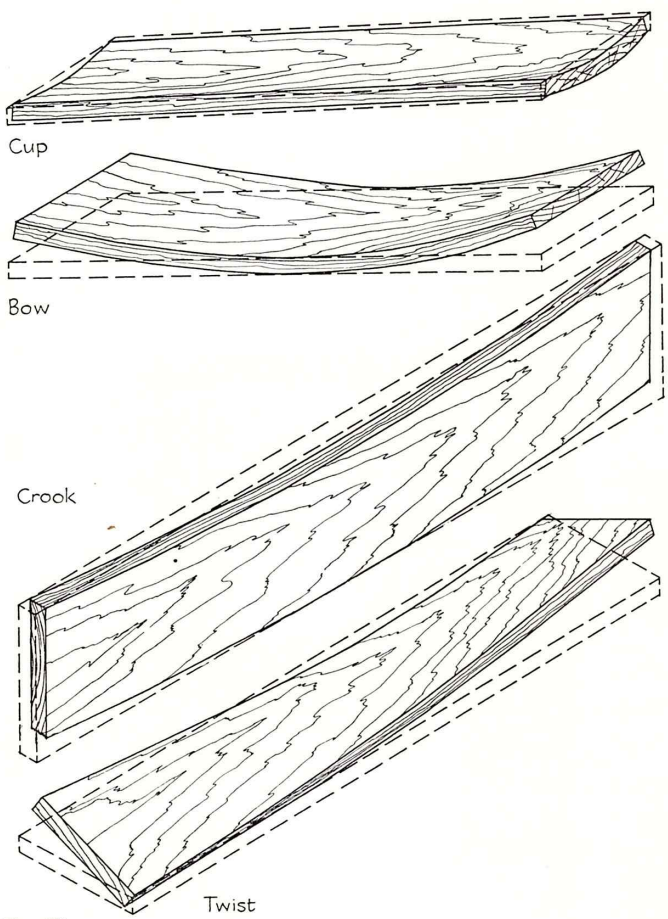


Fig. 75

Diagrams showing some seasoning defects

A *crook* is defined in the same manner as a bow but the term applies to a deviation in respect to the narrowest face or edge of a piece.

Cup is a curve or deviation from a plane surface across the width of a piece, and is the result of differential shrinkage. Cupping does not occur in a truly quarter-sawn board.

A *twist* is a spiral distortion.

A *shake* is a lengthwise separation of the wood fibres which has developed during the growth of the tree, e.g., heart-shake in rimu.

A *split* is a lengthwise separation of the wood due to the tearing apart of the wood cells.

A surface check is a lengthwise separation of the wood fibres due to the surface shrinkage during the process of drying.

Note: The New Zealand Standard Specification 169 *(National Grading Rules) provides a detailed description of blemishes and defects occurring in timbers.*

Insects attacking timber

Insects tunnel in timber, spoil its appearance, and, where tunnels are numerous, can so reduce strength properties as to make the timber valueless. Some insects attack only living trees or newly felled logs, some only seasoned timber.

Life cycles of insects

Most persons are familiar with the stages of development, called the life cycle, of butterflies, from egg to caterpillar or larva, followed by a resting or pupation stage as a chrysalis until the emergence of the adult butterfly. Most insects that attack timber have a life cycle similar to that of the butterfly.

The life cycle of the termite is different in that the insect hatched from an egg is a small edition of the adult insect except that its wings and reproductive organs are undeveloped. During growth the immature insect moults several times until the adult stage is reached.

***Common house borer* (*Fig.* 76)**

The common house borer (*Anobium punctatum*) shows preference for the sapwood of both hardwoods and softwoods, but the heart timber is not immune from its attack. Heart totara and heart kauri are, however, very resistant to attack, as also are some exotic timbers such as oregon and redwood. This insect will attack timber

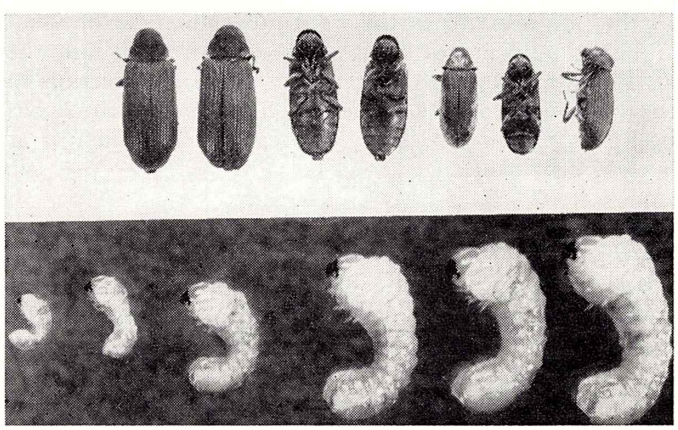


Photo: Cawthron Institute × 5

Fig. 76

Common house borer (Anobium punctatum)
Upper photo – Adults Lower photo – Larvae

of low moisture content only and green timbers are not damaged. The attack of the common house borer may be noticed in any part of a house, but foundations, match-linings in kitchens, laundry, and weather-boards on the shady side of a house are usually the first to be damaged (*Fig.* 77).

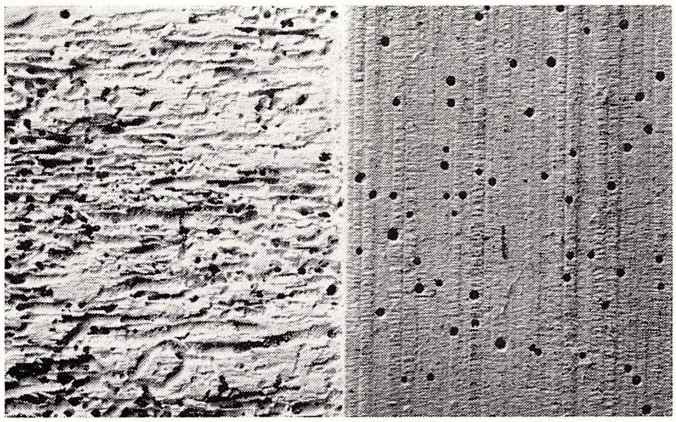


Photo: R. Blick × .7

Fig. 77
Damage to timber by house borer (Anobium punctatum)

Life cycles

Eggs are laid in dark places such as old flight holes, as well as in cracks, crevices, and joints but never on perfectly smooth surfaces. The eggs hatch after a period of approximately three to four weeks. The larva commences to bore in any direction in the wood and when mature it bores its way close to the surface where it hollows out a small pupal cavity in which it changes from the larva to the pupa. This pupal cavity may be less than $\frac{1}{32}$ in. below the surface. The winged insect, upon emerging from the pupa, remains in the chamber until its body has become hard and firm, when it commences to bore its way out of the wood. When this boring commences some fine bore dust may be pushed out and this is often the first indication of an infestation. The insects emerge in greatest numbers during the months of November to March when they can be seen on walls, window sills, etc. The holes (flight holes) left after the emergence of the insect are round and from $\frac{1}{32}$ in. to $\frac{1}{16}$ in. in diameter. Soon after emergence the insects mate and the female starts depositing eggs and the life cycle starts again. Experimental work carried out in New Zealand shows that the whole life cycle may take from three to four years.

The adult insects vary from $\frac{1}{10}$ in. to $\frac{1}{4}$ in. in length, are boat shaped and red-brown to dark-brown in colour. The thorax is shaped like a hood and completely covers the head of the insect giving it a hooded appearance. The insects are reported to be most active at dusk and during the night, although attracted in daylight to those portions of the buildings receiving direct sunlight. Generally they tend to inhabit old flight holes by day and to lay large numbers of eggs in them.

Anobium magnum

Fig. 78 is an illustration of a boring insect that is larger than the common house borer. It is found only in timber which is infected by fungi and is therefore present only in damp ill-ventilated situations. The flight holes are larger than those of the common house borer, being $\frac{3}{32}$ to $\frac{1}{8}$ inch in diameter and circular in outline. Damage by this insect, in severe cases, can reduce the interior of a piece of wood to powder and only the outside surface remains as thin laminae.

***Powder-post beetles* (*Fig.* 79)**

The powder-post beetles (*Lyctus* species) have a life cycle of one year and lay their long, cylindrical eggs in the cavities of exposed *hardwood* vessels, never in cracks or crevices. Unless starch is present, as it is in sapwood, the larvae cannot feed, and therefore the attack of these beetles is confind to the sapwood (*Fig.* 80). Once the sapwood has been destroyed the beetles abandon the timber and all attack ceases. As these beetles infest hardwoods only, they are chiefly found in tawa, taraire, and oak timbers.

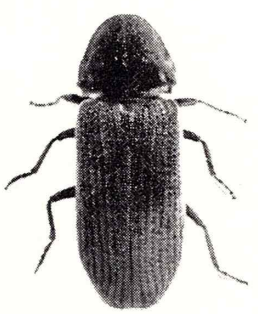


Fig. 78 *Photo: D. Read* × 6.5
Anobium magnum

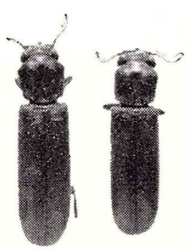


Fig. 79 *Photo: D. Read* × 6.75
Powder-post beetles
(Lyctus brunneus)

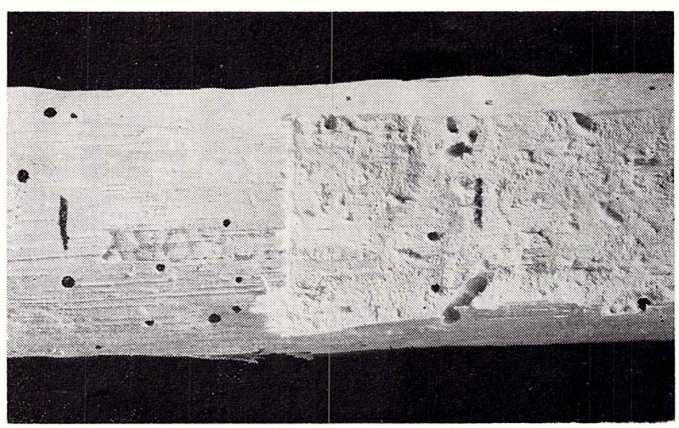


Photo: R. Blick × 1

Fig. 80
Timber damage by Powder-post beetles (*Lyctus* sp.)

Life cycle

The eggs hatch in from eight to twenty-five days and the larva immediately bores into the timber, tending to follow the grain much more closely than the common house borer. The *frass* (dust from boring) produced is fine and tightly packed as compared with the gritty and loosely packed frass of the common house borer. The pupal chamber is constructed close to the surface of the wood and the beetles emerge at about the same time as the common house borer. The round flight holes vary in size from $\frac{1}{32}$ in. to $\frac{1}{16}$ in.

The adult beetle is somewhat flat, elongated, and black to brown in colour. It varies in length from $\frac{1}{10}$ in. to $\frac{1}{17}$ in. These insects are distinguished from the common house borer by the fact that the head is visible from above, projecting beyond the hood formed by the thorax. Unlike the common house borer they seldom fly during the day, shunning the light and collecting on the dark undersurface of infested timber.

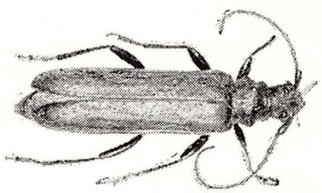


Photo: N.Z. Forest Service

Fig. 81

Adult of two-toothed longhorn borer
(Ambeodontus tristis)

Two-toothed longhorn (*Fig.* 81, 82)

The two-toothed longhorn (*Ambeodontus tristis*) is a native insect which has changed its habits of life so that instead of being confined to the forest it can now infest house timbers. It attacks a large range of timbers including rimu, totara, matai, kauri, miro, and macrocarpa. It will attack both the sapwood and the heartwood. As the insect prefers dark places it will be found mostly in the foundations of a house, infesting piles and other timbers below floor level, but this does not mean that other parts of the house are immune from attack. Unlike the common house borer which, although severely damaging timber, seldom causes its complete failure, the two-toothed longhorn will, through its burrowings, reduce the timber to a mere shell before there are many holes betraying the presence of the insect. Infested timber may therefore be first detected by its failure.

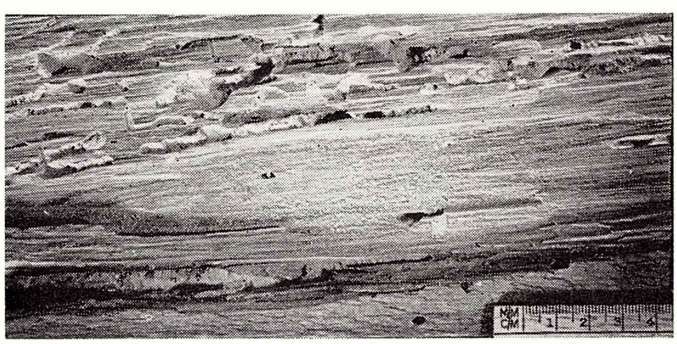


Photo: N.Z. Forest Service

Fig. 82

Timber damage by two-toothed longhorn borer

Life cycle

Eggs are deposited, often in batches, in cracks or grooves of the timber, in joints, or under splinters. Upon hatching, the larva enters the wood and tunnels through the timber working along the grain. As the burrowing proceeds the larva grows in size and the tunnel widens, the bore dust being packed tightly behind the larva. During feeding the larva eats the wood from side to side leaving faint markings running round the walls of the tunnels. The tunnels are in some cases remarkably long, extending for many feet. When attacking structural timbers the larva is able to pass across joints, i.e., it may pass from a joist to a plate or vice-versa. When fully grown the larva excavates a pupal chamber and passes to the pupal stage, still some distance from the surface. Upon emerging from the pupal chamber the adult beetle bores its way out of the timber leaving a characteristic oval flight hole which may measure $\frac{1}{4}$ in. across the longer axis. After emergence males and females mate and the female starts to lay eggs.

The adult beetles emerge in the greatest numbers during the months of April, May, and June. The length of time taken to pass from the egg to the adult stage is at least three years.

The adult insects are from $\frac{1}{2}$ in. to 1 in. in length, chocolate brown in colour, and elongated and tapering in form. The antennae are long and conspicuous. They are easily identified by a pyramidal spine on each side of the fore thorax while on the upper surface a pair of knot-like swellings project.

The beetles shun bright light and prefer to emerge on the concealed surface of the wood such as the underside of floors, etc., where the flight holes ordinarily go unnoticed.

Pin-hole borer (*Fig.* 83, 84)

The pin-hole borer will attack only standing trees or newly felled logs and for this reason is not of importance in structural timbers, although it causes defects in dressing lines. The flight holes resemble very closely those of the common house borer but can be readily distinguished from them as the tunnels of the pin-hole borer are lined with a blackish material which stains the wood surrounding the flight holes. *Fig.* 84 shows a piece of timber which has been attacked by the pin-hole borer.

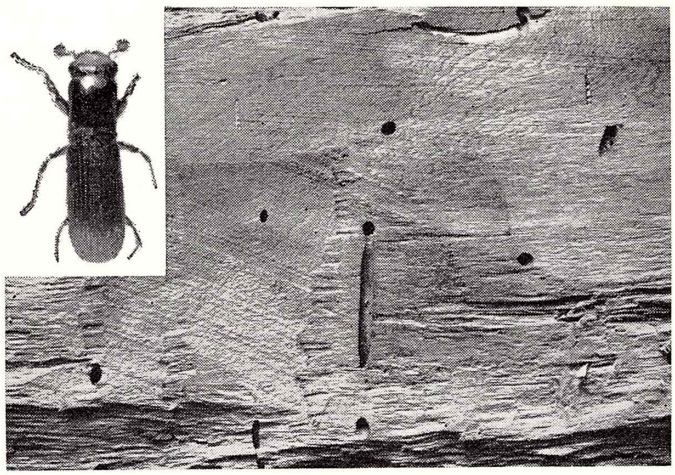


Photo: R. Blick × *5.6*

Fig. 83
Adult of pin-hole borer (Platypus douei) (*inset*)

Photo: Cawthron Institute × *1.4*

Fig. 84
Timber damage by pin-hole borer (Platypus sp.)

Precautionary measures

Precautionary measures against the common house borer and the two-toothed longhorn are essentially the same. Buildings should be constructed so as to allow for adequate ventilation and exterior timbers should be kept thoroughly painted. Rubbish and debris should always be removed from underneath a house and the storing of timber (firewood, etc.) in such places discouraged. Leaks, either through the roof or through faulty spouting or taps, should be prevented, and the presence of vegetation in close proximity to a house should be avoided. Some infestations can be traced to timber yards; in these yards the racks, fillets, and odd ends may be infested and these in turn serve to spread the infestation to the stacked timber. When large quantities of susceptible timber have to be used for building purposes preventive, preservative treatment should be employed.

Routine inspections of the exterior and interior woodwork of a house should be carried out by the property owner. In the interior of buildings and in furniture, signs of active attack are readily available in the new appearance of new flight holes, the insides of which appear quite fresh and light coloured. In exterior timbers the flight holes weather rapidly and additional evidence must often be looked for. Discharge of frass from exit holes is evidence of attack. This discharge may take place at practically any time of the year owing to newly created frass being forced out through old flight holes, but it is most noticeable at the time the insects are approaching the surface to form their pupal chambers. Inspections should therefore begin about October in the North Island and December in the South Island and continue at appropriate times.

Even where no flight holes are visible a discharge of frass may take place at joints or cracks in the timber as the larvae pass these points in their borings. In the case of the powder-post borers you may at times see a minute discharge through the vessels of the hardwoods infested.

Particular attention should be paid to attacks by the two-toothed longhorn. The damage done by these insects may extend for several feet beyond the last flight holes. Heavily infested flooring should be removed and, if the attack has spread to floor joists, heavy injections of a preservative should be applied. All damaged timber which has been removed should be burnt at once.

In buildings where the attack of wood-boring insects is localised, appropriate measures taken will fully repay the expenditure of considerable time and money. These measures include:

(1) Removal of badly infested timber;

(2) Treatment of infested timber with a reliable wood preservative; and

(3) Carrying out the instructions detailed above.

On the other hand in buildings where the attack is widespread and far advanced any treatment is of doubtful value.

Termites

Termites live in colonies (*Fig.* 85) varying from several hundreds to thousands of insects. Each colony is maintained by a reproductive or "royal pair" known as the

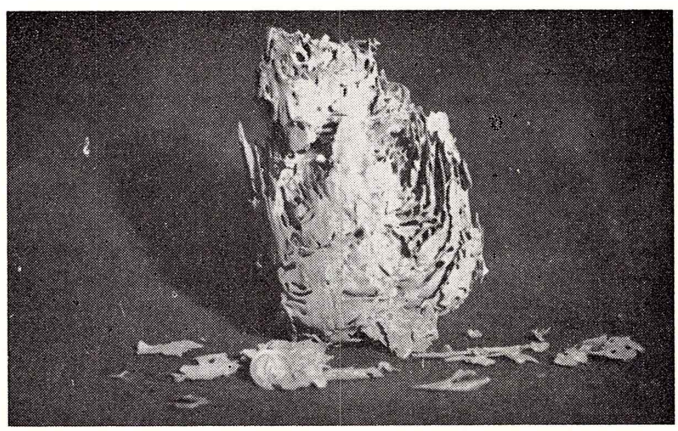


Photo: H. C. Mullions

Fig. 85
Nest of Australian termite colony (Coptotermes sp.)

king and queen. The eggs laid by the queen termite produce broods of immature termites called nymphs, some of which eventually develop into workers, soldiers, or reproductives (*Fig.* 86). When either the king or the queen of a colony dies, or when part of a colony is cut off from the parent colony, emergency reproductive forms develop from some of the nymphs, or the eggs,

and take the place of the original parents and so maintain the isolated part of the colony. Under such circumstances a parentless part of a colony may be transported in timber to a distant place and continue to survive.

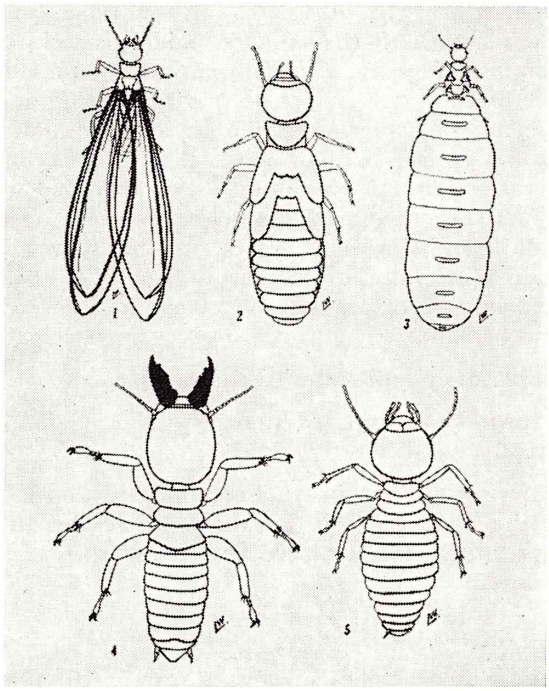


Fig. 86 *Photo: Cawthron Institute*

Different stages in life cycle of termites

(1) *Alate or winged form* (3) *Queen*
(2) *Nymph* (4) *Soldier*
(5) *Worker*

It is the blind, wingless, and sterile worker that attacks and damages timber. Though the workers are soft-bodied, their small horny jaws enable them to eat particles from the wood in which they live.

Each year during the period from November to March the winged sexually mature reproductives swarm in countless thousands from the colony and disperse in all directions. After flight the male and female reproductives mate and seek an entry into timber by way of cracks and nail holes, where they establish new colonies. Dry-wood termites require comparatively dry conditions for their well-being, but the earth-dwelling termites form a colony in the ground, in the base of a post, pile, or hollow tree.

Food of termites

The food of termites consists of cellulose, and the types we are interested in live in close association with timber. When attacking timber, termites excavate extensive passageways in the interior of the wood to such an extent that finally nothing is left but a mere outer shell.

Types of termites

Of the different types of termites known to occur in New Zealand two types only are of importance to us, namely: (1) *dry-wood termites* and (2) *earth-dwelling termites.*

Dry-wood termites are able to live under comparatively dry conditions such as in timber with as low a moisture content as 10 per cent. Dry-wood termites are natives of New Zealand and their whole life is spent in timber either in wood structures or in trees, the colonies being found above the ground. In addition to the native species there are certain species of Australian dry-wood termites which have reached New Zealand, but as far as is known they are found only in railway-sleepers and hardwood poles. Dry-wood termites attack timber by hollowing out wide tunnels through it, leaving finally little more than a shell (*Fig.* 87). Throughout these tunnels are found numerous round hard pellets (coffee grains) and as no other wood-boring insect produces such pellets their presence indicates attack by dry-wood termites.

Earth-dwelling termites

There are no earth-dwelling termites native to New Zealand but certain species that have reached the Dominion from Australia have become established at Auckland and New Plymouth at least. Owing to their destructive powers earth-dwelling termites are causing much anxiety. Earth-dwelling termites need moisture and it is for this reason that the main part of the colony is established in the ground at varying depths. This central colony may be in the ground beneath a building or some distance away in the base of a post or pole, or in a hollow tree. From the central colony the workers explore in all directions in their search for wood to attack. As the insects shun light they advance under cover by burrowing through the ground, or by constructing earth-covered runways on the surface of any timber, concrete, or brick foundations, etc. until they find a suitable point of entry.

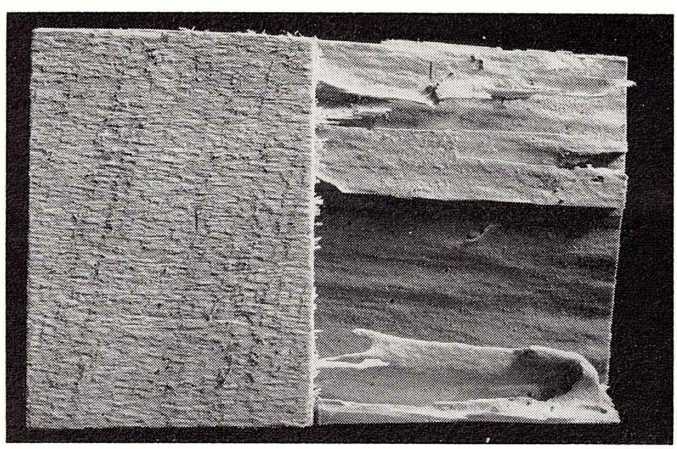


Photo: R. Blick

Fig. 87

Timber damaged by termites — N.Z. drywood termites (Calotermes brouni)

Fig. 88 shows timber damage by Australian subterranean termites and *Fig.* 89 a earth-covered runway on a post and *Fig.* 90 a runway on a concrete wall. *Fig.* 91 demonstrates how subterranean termites form runways from the ground to the foundation timbers of a house.

Once entry is made destruction is rapid, extending from the foundations to the rafters. The timber is eaten out and becomes completely riddled with tunnels leaving, in extreme cases, only a thin shell. The tunnels are lined with clay which is hard and brittle. Earth-dwelling termites have been known to attack both the heartwood and the sapwood of rimu, kauri, matai, totara, Australian hardwoods, oregon, radiata pine, blue gum, and macrocarpa.

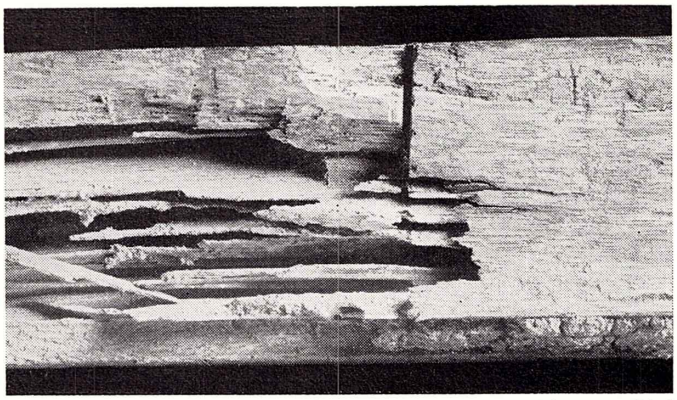


Photo: R. Blick

Fig. 88
Timber damaged by termites – Australian subterranean termite (Coptotermes sp.)

Prevention and control

Prevention of termite attack involves the removal from beneath buildings and from their vicinity of all builder's rubbish, all remnants of shrubs and trees, including stumps and roots. Attention should also be given to unsound poles, fence posts, and hollow trees. The storing of wood of any kind beneath a building and the burying of wood fragments in fillings after a building has been erected should be avoided. Timber from demolished infested houses should be burnt and not sold, as the selling of this timber spreads not only termites but other wood-boring insects to uninfested localities.

An annual inspection of wooden buildings should be carried out by property owners and particular attention given to the foundations and all wooden parts near the ground. A heavy chisel should be used to sound inspected timber which will collapse if badly infested. During the warmer months of the year termites swarm and the presence of these swarms is a certain indication that a termite colony is in the vicinity. If earth-dwelling termites are present their earthen runways should be visible under the floor. In bad cases of infestation these runways could be inside the building along skirting-boards or following the angles of walls. If termites are found to be present the local authority or the State Advances Corporation should be notified as the control of earth dwelling termites is an expert's job.

In infested areas foundation walls and piles should be of concrete or brick and of sufficient height to allow adequate ventilation and inspection. The foundation walls and piles must also be fitted with termite stops or caps (*Fig.* 92).

These stops may be made of heavy-gauge copper or galvanised iron and they should overhang 2 in. beyond the inside face of the foundation wall or pile and be turned down as shown in *Fig.* 92. Such barriers prevent earth-dwelling termites from gaining access to the tim-

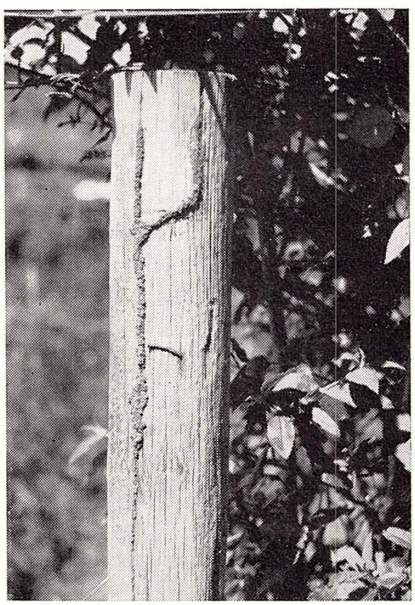


Fig. 89 *Photo: H. Mullions*
Covered earthen runway of Australian subterranean termites on a post near a termite colony

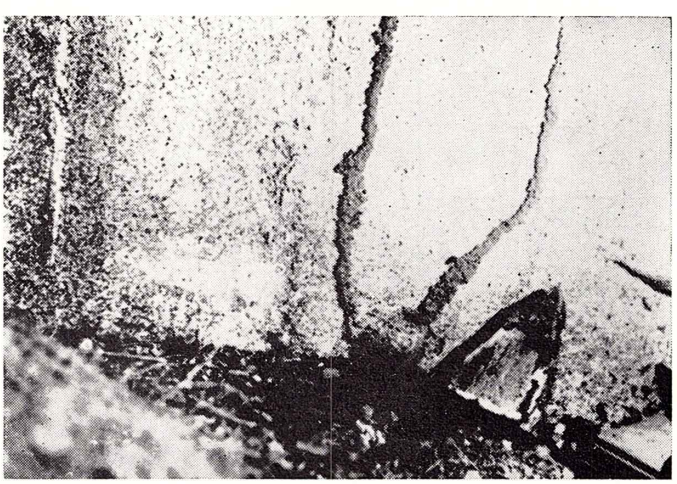


Photo: H. Mullions

Fig. 90
Covered earthen runway on concrete wall

bers of the house, as the insects seem unable to construct their enclosed runways in a downward direction. The following precautions should be observed when termite stops are being fixed:

(1) The stops should be placed at least 12 in. above the surface of the ground.

(2) All joints or holes should be soldered.

(3) The usual damp-proof course should be placed immediately below the stop.

(4) Service pipes rising from the ground or passing through foundation walls should have stops, in the form of cones soldered to them.

(5) Concrete floors in porches, laundries, etc., should be isolated from structural timbers by suitable stops.

(6) Cracks in concrete floors should be avoided.

With New Zealand dry-wood termites such barriers are useless, as these insects enter from the wing at any convenient crack, nail hole, etc., and the best that can be done under the circumstances is to maintain the building in as sound a state of preservation as possible.

The Termite Act 1940 gives certain powers to local authorities and the State Advances Corporation of New Zealand for the detection, control, and destruction of earth-dwelling termites. This Act applies only to introduced species of termites and not to native ones.

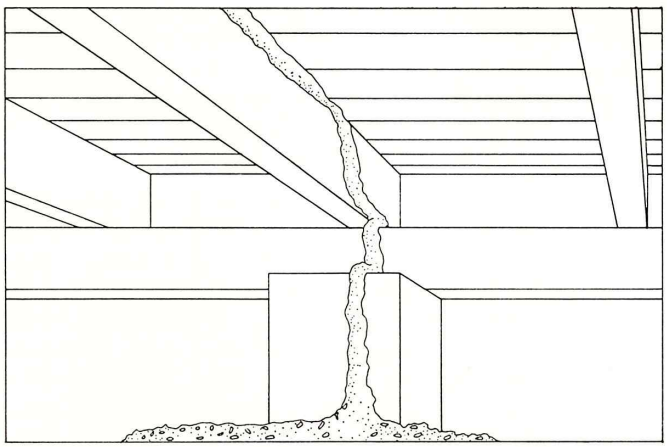


Fig. 91

Earthen covered runway of subterranean termite colony under a house

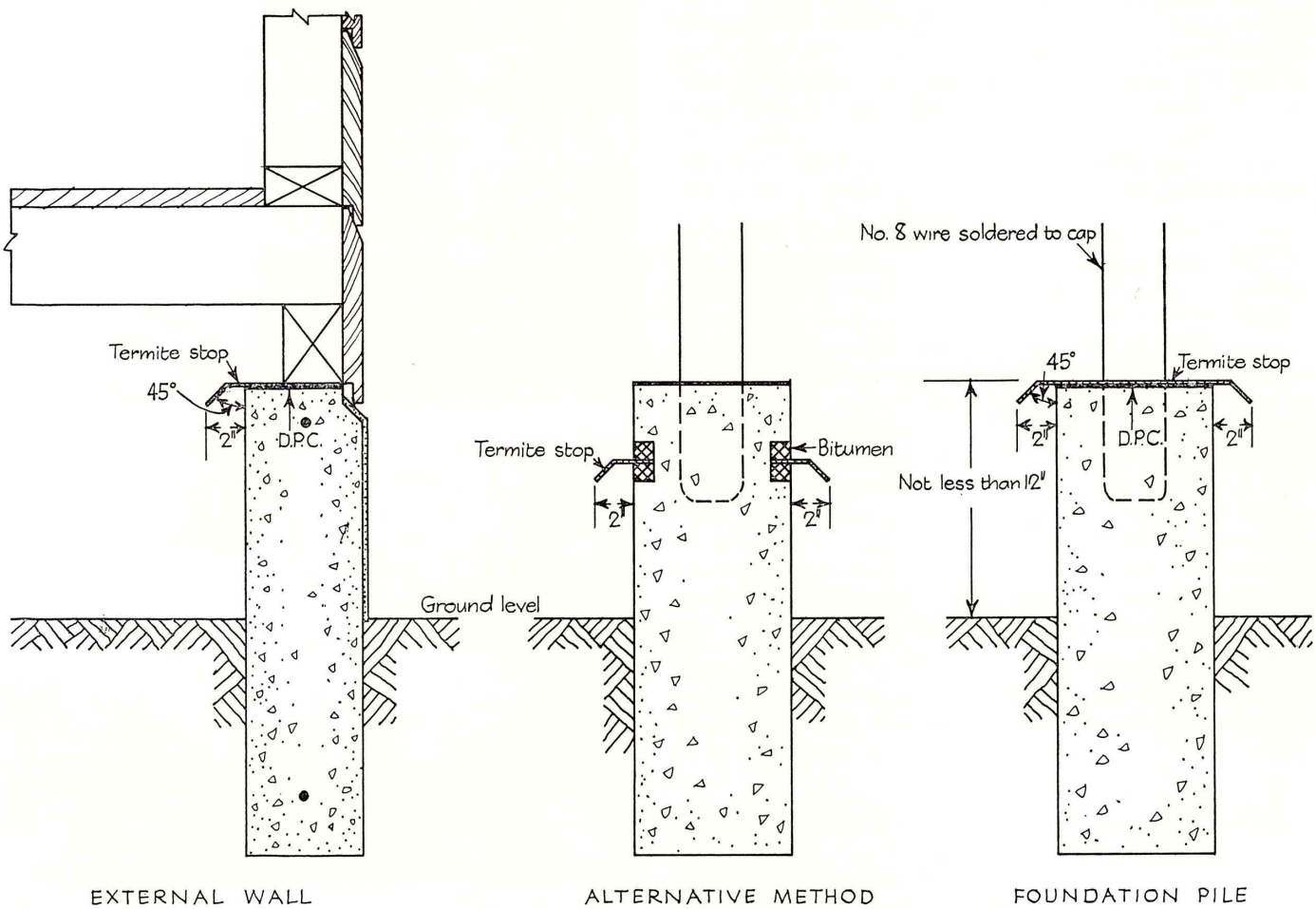


Fig. 92

Termite stops and caps on foundation walls and piles

Fungal infection

Fungi are plants which lack chlorophyll and in consequence cannot manufacture the starch or sugar essential for plant growth.

Fungi, however, have special root-like structures called *hyphae* which can dissolve out the necessary starches and sugars already manufactured by other plants. It is for this reason that the fungi in which we are interested are always in close association with timber.

The hyphae, which are exceedingly fine tubes or hollow threads, eventually become matted together forming a felt-like mass. This felt-like mass is called the *mycelium,* and it is from the mycelium that the fruiting body (flower of normal plant) arises. The fruiting body sheds spores (seeds of normal plant) and from these spores, when conditions of moisture and temperature are right, fresh hyphae grow.

Types of fungi

Sapstain fungi or moulds

Sapstain fungi live on the contents of the cells but do not attack the cell walls and for this reason do not cause decay or significant loss of strength of the timber attacked.

Sapstain fungi occasionally cause partial blue staining of wood in standing unhealthy trees, but are more of a problem in log storage and timber seasoning. Many light-coloured woods are disfigured by these fungi as a result of the block stacking of timber as it comes off the saw in a green condition. Immediate filleting for air seasoning, where conditions are favourable to rapid drying, may obviate the need for protective treatment, but in most localities in New Zealand a chemical anti-sapstain dip is the best insurance. Disfigurement by sapstain fungi is most noticeable in the exotic pines and kahikatea. The presence of sapstain on timber indicates poor handling practice and consequent exposure to conditions favourable to decay.

Rot fungi

Rot fungi not only live on the cell contents but also attack the cell walls. Timber attacked by a rot fungus becomes brittle, dry, and will crumble readily at touch. The fresh smell is replaced by a musty odour and if tapped the timber does not give the "ring" of sound wood. Timber is reduced, in fact, to a shrunken mass without strength and use.

A 20 per cent moisture content is the minimum for the growth of *all* fungi and although one species, *Merulius lacrymans,* is called the dry rot fungus it still needs for growth a 20 per cent moisture content.

Merulius lacrymans has caused much concern in buildings of brick construction in Britain but its incidence in wooden buildings in New Zealand has fortunately been rather limited. This fungus can send forth special hyphae which can penetrate the mortar of brickwork, porous concrete, or cross steelwork to reach damp conditions. These hyphae are then able to convey water from these damp situations to where the main body of the mycelium is growing. Under these conditions it may be found that timber seemingly in a dry condition is rotting; hence the name dry rot.

Fuscoporia species are the most common rot fungi found in wooden buidings in New Zealand. The fruiting body is like a covering of light brown velvet on the affected timber.

There are many other rot fungi but they all have in many respects the same characteristics. All rot fungi require food (a suitable wood), a supply of moisture, a stagnant atmosphere, and a suitable temperature, and there must, of course, be a source of infection.

Conditions essential to fungal growth

Conditions suitable for attack by fungi are mainly caused by:

(1) The use of timber with a high moisture content in positions where it is unable to dry within a reasonable time.

(2) Building upon damp sites without the provision of adequate surface drainage.

(3) The failure to provide efficient damp-proof courses between brick or concrete and wood.

(4) Inadequate under-floor ventilation.

(5) Leaking downpipes, spoutings, etc., causing timber in the vicinity to become damp.

(6) Brickwork cavities bridged by mortar droppings along which water can pass to timber structures.

Prevention of fungal attack

The best prevention against fungal attack is to keep the timber dry, and if this is done there need be no fear of an attack. All the conditions mentioned previously dealing with the causes of fungal attack should be avoided. Adequate under-floor ventilation is of extreme importance, and the dangers of fungal attack may be largely overcome by the adoption of proper building practice and maintenance of houses. During building operations, odd bits of wood should be removed from underneath the house as these, being in contact with the ground, rot quickly and if conditions are suitable fungi may spread from them to the house timbers. When the dangerous dry rot (*Merulius lacrymans)* is found, extra care should be taken to destroy infected timber and infected masonry should be sterilised with a suitable fungicide or flame-cleaned with a blow-lamp.

Timbers showing fungus damage should be removed and replaced with sound timber. The timber for some distance from the point of attack should also be removed, as it is difficult to decide merely by inspection how far the fungus attack has actually proceeded. The cause of

the attack should be traced and remedied. If the structural defects causing the attack cannot be remedied all the new timber should be preferably heart (heart timber is not so liable to attack), well seasoned, and treated with some reliable preservative.

During an inspection of premises for fungal attack, you will find that the effects of weathering are much the same as fungal infestation, but must not be mistaken for it. Constant exposure to the weather results in a softening of the surface of the wood, and repeated wetting by rain, followed by rapid drying in the sun, leads to the development of numerous surface checks or splits which resemble those produced by some forms of fungal attack. Once these conditions are established the wood is, of course, in a favourable state for fungal infection. A mechanical barrier is essential to combat weathering and for this a good paint is best.

Paint will not always prevent fungal attack and in certain cases is a predisposing factor. In these cases painting has been done before the timber has thoroughly dried and in consequence has had the effect of sealing the moisture in and so rendering the timber much more liable to fungus attack. Similarly creosote, hot tar, and other preservatives of this nature must not be used until the moisture content of the timber is below 20 per cent.

Wood Preservation

It is well known that some timbers are most durable than others, and the reason for this is that durable timbers contain resins and other naturally occurring compounds which are poisonous to wood-rotting fungi and wood-boring insects. This natural durability of timber is usually confined to the heartwood, as the compounds which make the timber durable are only formed by the living tree in the wood which is changing from sapwood to heartwood.

Timbers lacking these poisonous compounds are non-durable. This does not mean that they will rot in all cases, but it does mean that if they are exposed to conditions which permit the establishment and growth of certain fungi or wood-boring insects they will quickly become infested and their service life will be short.

Wood preservation is therefore necessary in order to obtain an economic service life from timber of little natural durability, such as the sapwood of native species and the sapwood and heartwood of some exotic species.

The preservation process consists in coating or impregnating timber with certain chemicals which render the timber poisonous or uninhabitable to wood-destroying organisms. There is no perfect wood preservative made to suit all timbers and conditions but there are many substances that help to preserve timber, some being more effective than others. All possess certain disadvantages that limit their use, and a choice of a preservative depends upon the particular purpose in mind.

Properties of a preservative

For general purposes a wood preservative must have the following properties. It should be:

(1) Highly poisonous to fungi and insects.

(2) Readily absorbed by wood.

(3) Chemically stable and permanent so that it will remain in the wood for many years.

(4) Safe to handle and easy to apply.

(5) Harmless to metal or wood so that treatment plants will have a long life and metal fittings, nails, and screws in contact with the treated wood will not be affected.

(6) Cheap and readily available.

(7) Fire resistant or at least not liable to increase the inflammability of wood.

(8) Free from odour or colour.

(9) Free from effect on subsequent painting.

(10) Not liable to cause wood to swell.

Types of preservatives

There are three general classes of preservatives, namely:

(1) Those derived from coal tar (creosote). These are relatively insoluble in water and do not evaporate easily.

(2) Inorganic salts, e.g., *zinc chloride,* which are soluble in water.

(3) Preservatives that consist of a small percentage of a highly toxic chemical dissolved in oil, e.g., *pentachlorphenol.*

Preservatives derived from coal tar

Coal-tar creosote is a black or brownish oil made by distilling coal tar. It is a most effective wood preservative with the following advantages:

(1) High toxicity.

(2) Relative insolubility in water resulting in a great degree of permanence when used out of doors.

(3) Ease of application.

(4) The ease with which its depth of penetration can be determined.

(5) General availability and relatively low cost.

It has certain disadvantages, however, namely:

(1) Freshly creosoted timber can be ignited easily and will burn readily.

(2) The odour is unpleasant to some persons and may be considered objectionable in dwellings.

(3) The colour and the fact that it cannot be painted over easily make it unsuitable for timber designed for painting.

(4) It is liable to stain and damage finished work in contact with it.

Creosote does not water-proof timber to any great extent, its efficiency as a wood preservative being due entirely to its high toxicity to wood-destroying organisms combined with its high degree of permanence.

A grade of creosote conforming to the New Zealand Standard Specification for Coal-tar Creosote for the Preservation of Timber should always be used when the condition and situation of the timber require the application of creosote.

Water-soluble preservatives

The advantage of water-soluble preservatives over creosote is that they leave the timber clean, odourless, and in most cases paintable. They have certain disadvantages, however, namely:

(1) Except for this diffusion process, the timber must be seasoned both before and after treatment.

(2) Water will gradually leach the water-soluble salts from treated timber.

Water-soluble preservatives should not be used if the timber will be exposed to conditions under which leaching may be severe, except for those types which have been shown by tests to withstand leaching.

Some of the more commonly used water-soluble preservatives are *zinc chloride, chromated zinc chloride, copper sulphate, sodium fluoride, boric acid,* and *borax.* Proprietary lines include *Boliden salts, Wolman salts* (Tanalith), and *Celcure.*

Oil-soluble preservatives

These preservatives consist of toxic chemicals which dissolve in oil but not in water. After timber has been treated with a solution of one of these preservatives, the solvent (oil) evaporates, leaving the chemical in the wood, and the surface of the wood clean, colourless, and odourless. These preservatives penetrate wood slightly better than creosote or water-soluble preservatives and so are better for brushing or spraying.

Timber treated with oil-soluble preservatives in kerosene or similar vehicles can be painted satisfactorily provided sufficient time is given for the solvent to evaporate.

When oil-soluble preservatives are sprayed in confined or ill-ventilated spaces a respirator should be used as it is possible for the atmosphere to be charged to toxic limits with vapour. *Copper naphthenate, zinc naphthenate,* and *pentachlorphenol* are the preservatives most commonly used.

Zinc and copper naphthenate

The naphthenic acids from which zinc and copper naphthenate are obtained are derived from petroleum. These acids are used extensively as paint dryers and it is their salts, such as zinc or copper naphthenate which are used as wood preservatives. Both zinc and copper naphthenate are costly compared with say, creosote, and are not generally used in pressure-treating plants, but are applied by dipping. brushing, spraying, or injecting. The naphthenates can be bought ready to use in solution or as concentrates for subsequent dilution with power kerosene. The concentrations used are: zinc naphthenate 2 per cent metal by weight, and copper naphthenate 1 per cent metal by weight.

Pentachlorphenol

This is a chlorinated phenol and is marketed in crystal form. A minimum concentration of 5 per cent by weight is used for the preservation of timber, but a 7 per cent concentration would be preferable for outdoor use.

Concentrated solutions of pentachlorphenol (50 per cent) are on the market and the dilution of this solution with power kerosene or dieseline is a simple procedure.

The formation of crystals of pentachlorphenol on the surface of treated wood as the solvent evaporates is an objectionable result of the use of this preservative, but if sperm oil or castor oil is incorporated in the solution it will help to stop crystals from forming.

Preservative processes

The only completely satisfactory methods of wood-preservation employ processes whereby the entire substance of the timber is penetrated by the preservative. Less efficient methods, such as surface treatments, provide an envelope of preservatised wood around an untreated interior but this superficial layer of treated timber is capable of penetration by insects which then establish themselves in the untreated interior. Complete penetration is obviously necessary for timber likely to be cut, dressed, bored or notched after treatment; otherwise untreated surfaces may be exposed.

The Timber Preservation Authority, approves preservation treatments and all timber-treatment plants must be registered with this body.

Pressure processes

There are two pressure processes in common use, namely, the *full cell process* and the *empty cell process.* The main feature of both is the treating cylinder, which is a horizontal cylindrical vessel fitted with an airtight door. The timber to be treated is stacked on steel cars which run on rails into the treating cylinder. Piping connects the treating cylinder with storage tanks of preservative, with compressed air and vacuum pumps, and with a supply of steam for raising temperatures.

Full-cell process

The full-cell process is carried out as follows:

(1) After the charge of timber has been placed in the treating cylinder a vacuum is applied for half an hour or more to remove the air from the cylinder and as much air as possible from the wood cells.

(2) The preservative, previously heated to the correct temperature, is admitted to the cylinder without the admission of air.

(3) After the cylinder is full, pressure is applied until the right absorption of preservative is obtained.

(4) When the pressure period has been completed the preservative is drained from the cylinder.

(5) A short final vacuum is usually applied immediately afterward to free the timber from dripping.

In the full-cell process not only does the preservative enter the cell walls but the cell cavities also are filled.

Empty-cell process

The object of empty-cell treatment is to obtain deep penetration with low retention of preservative. Two empty-cell processes are commonly employed, both of which make use of the expansive force of compressed air to drive out part of the preservative absorbed during the pressure period. One of these processes is the *Rueping Process* in which the following procedure is employed:

(1) Air under pressure is forced into the treating cylinder which is already charged with timber. This pressure compresses the air in the cell cavities of the timber.

(2) The hot preservative is admitted to the cylinder and then the pressure is raised until the right absorption of preservative is obtained.

(3) The pressure is reduced to normal and so the air compressed in the cell cavities of the wood expands and pushes out the surplus preservative.

(4) A short final vacuum removes the surplus preservative from the wood.

The other empty-cell process, called the *Lowry Process,* is essentially the same as the Rueping Process except that the first stage of the Rueping Process is omitted.

Preservatives used in pressure treatments

Creosote can be used as the preserving solution in both cell types of treatment, but when water-soluble preservatives are used the pressure treatment is usually by the full-cell process.

Conditioning green timber for pressure treatment

In order to allow preservative fluids to enter wood cells it is necessary to remove most of the free water which occurs in the cell cavities. A moisture content of 18-20 per cent is generally considered satisfactory for pressure impregnation and this is usually obtained by kiln seasoning.

Diffusion process

For successful treatment by this process the timber must be green when treated because the gradual diffusion of the preservative into the wood from a concentrated source can take place only when both cell walls and cavities contain moisture.

Boron compounds are used as the preservative in diffusion processes. There are three different methods:

(1) Immersing the freshly sawn timber momentarily (a few seconds) in a highly concentrated solution of preservative followed by block stacking for four to six weeks.

(2) Immersing the timber in a hot (140°F.) solution at a low solution concentration.

(3) Steaming the timber and then introducing a cold solution of the preservative into the treating chamber.

Open tank or hot and cold bath process

This process is the most effective of the non-pressure treatments for applying creosote and the oil-soluble preservatives.

The treatment consists in heating the timber in the preservative in an open tank for several hours and then allowing the timber and the preservative to cool. An alternative to cooling is to transfer the timber quickly from the hot bath to another tank containing cold preservative.

Dipping process

In treating by the dipping process the timber is simply submerged in the cold preservative fluid and allowed to soak.

The period of soaking varies with the species and size of timber being treated. The penetrations obtained by this method are likely to vary from as little as $\frac{1}{16}$ in. to as much as 1 in., depending upon the kind of timber being treated.

All three types of preservatives can be used as the preserving fluid in this process.

Brush and spraying processes

These are the simplest methods of applying preservative to wood but they are also the least efficient. Creosote, preferably hot, and the oil-soluble preservatives are used in these methods. The oil should be flooded over the wood rather than merely painted upon it, and care should be taken to see that every check and depression in the wood is covered as otherwise access would be provided for wood-destroying insects. At least two coats should be applied, the second one after the first one has dried. The penetration of the oil will usually be less than $\frac{1}{16}$ in.

Brush and spray methods should be used only when more effective methods cannot be employed.

The use of preservatives in the treatment of infested buildings

Preservative material

Water-soluble preservatives are not generally favoured on account of their swelling and other effects upon the wood.

For exterior use creosote is undoubtedly the most effective material with which to treat wood against borer

attack, provided that its smell and the fact that a creosoted surface cannot be easily painted is not an objection.

For interior use and on painted surfaces any of the oil-soluble preservatives can be used although the ones most commonly used are the naphthenates and pentachlorphenol.

Methods of treatment

The initial treatment should be made at those times when the larvae are coming towards the surface of the wood and forming their pupal chambers. Subsequent flight holes should be treated also immediately they appear and a final treatment applied to the whole of the woodwork a few weeks after the appearance of the last flight holes made during the season.

The initial treatment aims at the destruction of the larvae. This can be achieved only by thoroughly impregnating the infested wood. Spray or brush treatment is of value in making the surface unsuitable for the depositing of eggs laid by the adult insect, but it is largely ineffective as regards the boring larvae. The larvae can be destroyed only by injecting a sufficiently large quantity of a preservtaive into old and new flight holes to penetrate the borings and impregnate the wood as much as possible.

While a hand-pressure pump of the nature of a large hypodermic syringe is useful for the purpose, the employment of firms equipped with special injector guns is justified for heavy infestations.

A thorough surface coating of preservative to all subfloor, roof, and ceiling timbers is desirable, even in addition to as thorough an impregnation as may be secured by injection guns.

In a new house where only one or two boards are attacked, they should preferably be removed and burnt.

It is not sufficient, however, to treat a building only once and imagine that the problem is solved. Two inspections should be made regularly each year in the early spring and the late summer or autumn and appropriate measures applied on each occasion. Furthermore each piece of timber brought on to the property at any time whether in the form of firewood, boxes, timber, furniture, etc., should be carefully inspected and where necessary treated. Failure to observe these precautions may result ultimately in reinfestation.

Utilisation of timbers

Some timbers are more durable than others and it is desirable that one should be familiar with the degree of durability possessed by the common building timbers.

Timbers treated in New Zealand are the non-heart timbers. Such pressure-treated timbers are generally accepted in place of heart-timbers and may be used on all kinds of work.

Preservative-treated radiata pine of suitable grades is generally acceptable for sub-floor framing, wall framing, roof framing and sarking, interior finishing and flooring, but is not acceptable for weatherboards or other exposed timbers, such as exterior joinery, unless the grade is high.

In most cases local authorities will accept tawa for flooring and interior finishing timbers provided it has been treated by the hot diffusion method to give a minimum core retention of 0·2 per cent of boric acid.

Table 5 gives a list of natural high-durability timbers and Table 6 a list of timbers which can be made to have high durability by treating them with deep penetration of a suitable preservative.

Table 5

High-durability Class—natural

Heart rimu	Heart red beech
Heart matai	Heart hard beech
Heart totara	Heart kaikawaka
Heart miro	Heart macrocarpa
Heart redwood	Heart kauri
Heart western red cedar	Heart tanekaha
Heart puriri	Heart kahikatea (yellow heart only)
Heart silver pine	

Table 6

High durability—imparted by deep penetration of preservative

Non-heart rimu	Non-heart tawa
Non-heart matai	Non-heart radiata pine
Non-heart totara	Non-heart corsican pine
Non-heart miro	Non-heart kahikatea
Non-heart European larch	

Durability is not, however, the only factor to be taken into account when deciding upon the species and quality of timber to be used for special purposes. Other important factors are density, strength, hardness, nail-holding power, ability to season satisfactorily, and stability. All these characteristics have to be weighed one against the other, but fortunately building trade practice has over the years established a sound guide for the use of different building timbers. The following is a summary of the timbers fulfilling the requirements for certain particular purposes.

Summary of building timber for specific purposes

(a) *Sub-floor framing*

Requirements are moderate strength and stiffness (about equal to Building A heart rimu), moderate durability, good nailing properties, and ability to remain straight after fixing in position.

Timbers generally suitable:

Heart rimu Building. A and B
Heart matai Building. A and B
Heart miro Building. A and B
} Standard timbers fixed in position green.

Rimu Building. A and B ....
Matai Building. A and B ....
Miro Building. A and B ....
Radiata pine No. 1 and No. 2 Framing grade .... } Deep preservative penetration required.

Heart European larch – locally grown
Heart red beech – fix in position green ....
Heart hard beech – fix in position green ....
Heart macrocarpa – locally grown ....
Heart kahikatea – yellow heart .... } Grades to be equivalent to grades of rimu.

Timbers suitable in dry locations—open foundations

Heart douglas fir (locally grown) – equivalent of Building A.

Heart radiata pine (resinous) – No. 1 and No. 2 Framing grade.

(b) *General framing — remaining dry in service*

Requirements are moderate strength and stiffness, good nailing properties, and ability to remain straight after fixing.

Timbers generally suitable:

Rimu Building A and B ....
Miro Building A and B ....
Totara Building A and B .... } Fixed in position partially dry. (40 per cent M.C.)

Radiata pine No. 1 and No. 2 Framing grade – install dry (20 per cent M.C.).

Beech species – install green ....
European larch – locally grown ....
Douglas fir – locally grown ....
Macrocarpa – locally grown .... } Grades equivalent to building grades of rimu.

Comment

It is desirable to decrease the span or increase the depth of beams in radiata pine and to use cement-coated nails if available. "Installation dry" for radiata pine is strongly recommended. "Installation green" for beech species and partially dry for rimu, matai, miro, and also European larch are recommended to avoid warping and to facilitate nailing.

(c) *General framing occasionally damp* (in exterior wall framing behind semi-porous sheatings, in bottom plates, and in rafters liable to get damp).

Requirements are as described for general framing (dry in service) except that a slight decay hazard may exist.

Timbers suitable are as listed for general framing (dry in service) except that radiata pine should be treated with preservative.

(d) *Weatherboarding and exterior trim*

Requirements are good painting, good machining and good nailing characteristics, freedom from warp, freedom from defects which are not waterproof or paintable or which cause distortion, and moderate durability.

Timbers specially suitable, with additional advantage of stability (minimum degree of working) are:

Heart rimu – Dressing A and B.
Heart matai – Dressing A and B.
Heart totara – Dressing A and B.
Heart miro – Dressing A and B.
Redwood – Dressing grade ....
Western red cedar – Dressing grade .... } Imported.

Timbers generally suitable are:

Rimu – Dressing or Building A (selected)
Matai – Dressing or Building A (selected)
Miro – Dressing or Building A (selected)
Kahikatea – equivalent to above ....
Tawa selects (extravagant use) ....
Tanekaha – equivalent to rimu grades
Pukatea – equivalent to rimu grades ....
Radiata pine – Dressing grade ....
Totara – Dressing or Building A (selected) } Preservative treated and well maintained with paint coats.

Comment

All these timbers left exposed after machining are liable to absorb water readily; also the priming coat is effective protection for about a month only. To avoid moisture pick-up, cupping, and checking, it is necessary to keep boards dry; apply undercoat before the primer weathers. Special care is necessary with radiata pine for which are recommended kiln drying and special priming treatment, including adequate sealing of knots.

(e) *Flooring* (subject to ground moisture effects)

Requirements are:

(1) For natural-finish uncovered floors:

Good resistance to wear (hardness and even texture) and good strength; attractive figure or colour; good machining and nailing; freedom from warp; low shrinkage; and moderate durability.

(2) For partially covered or covered floors:

Moderate wear resistance and good strength; good machining and nailing; freedom from warp, loose defects, and slivering; and moderate durability.

Timbers are:

Heart rimu – Dressing grade.
Heart matai – Dressing grade.
Heart miro – Dressing grade.
Heart tanekaha – equivalent to Dressing grade.
Tawa selects (general-type preservative or boric acid treatment).
Red beech – equivalent to Dressing grade.
Silver beech – equivalent to Dressing grade.

Rimu – Dressing grade ....
Matai – Dressing grade ....
Miro – Dressing grade .... } Preservative treated.
Tanekaha – equivalent to Dressing grade
Kahikatea – equivalent to Dressing grade
Kauri – equivalent to Dressing grade ....

Radiata pine – Dressing grade ....
Corsican pine - Dressing grade .... } Preservative treated.
Rimu – selected Building A ....
Matai – selected Building A ....
Miro – selected Building A ....

European larch – locally grown equivalent grade } Heart or preservative treated.
Douglas fir – locally grown equivalent grade

(f) ***Flooring*** (not subject to ground moisture effects or similar hazard)

Requirements are similar to paragraph (e) but no significant decay hazard.

Timbers are similar to paragraph (e) but admit:

Rimu .... }
Miro .... }
Radiata pine .... }
Corsican pine .... } Grades as above without preservative treatment.
European larch }
Douglas fir .... }
Tanekaha .... }
Kauri .... }

(g) ***Interior finish***

Requirements are good machining and attractive appearance with consequent limitations of defects and blemishes.

Timbers suitable are:

Rimu – Dressing grade or selected Building A.
Miro – Dressing grade or selected Building A.
Tawa selects (boric acid treatment preferred).
Radiata pine – Finishing grade.
Corsican pine – Finishing grade.
Silver beech equivalent to rimu as above.

(h) ***Kitchen joinery and shelving***

Requirements are good machining, wide widths, freedom from defects affecting painting, freedom from significant tainting. Light colour preferred.

Timbers suitable are:

Rimu – Dressing grade, or selected Building A.
Miro – Dressing grade, or selected Building A.
Radiata pine – Factory grade (clear cuttings).
Tawa selects (low preservative retention with boric acid or similar colourless preservative).
Kahikatea – equivalent to Dressing grade rimu (low preservative retention as for tawa).
Silver beech – equivalent to Dressing grade rimu.

(i) ***Window joinery, exterior doors and frames***

Requirements are moderate durability, good painting properties, minimum degree of "working" good machining, freedom from defects and warping. Light weight preferred for sashes.

Timbers suitable:

(1) *For sashes and doors*
Timbers with outstanding merit are:
Heart totara – dressing grade.
Heart redwood – clear grade .... } Imported.
Heart western red cedar – clear grade }

Timbers suitable also include:

Heart kahikatea – Dressing grade.
Kahikatea – Dressing grade (treated).
Heart macrocarpa – Dressing grade (equivalent).
Totara – Dressing grade (treated).
Radiata pine – Factory grade (treated).
Heart alerce – Dressing grade (equivalent).
Heart kaikawaka – Dressing grade (equivalent).
Heart matai – Dressing grade or matai (treated).
Heart rimu – Dressing grade or rimu (treated).
Heart tanekaha – Dressing grade or tanekaha (treated).
Heart douglas fir – Dressing grade (equivalent).

Comment:

The last four timbers, being dense, are more especially suitable for fixed sashes.

(2) *For stiles, mullions, and heads*

Timbers suitable are:
Heart totara – Dressing grade and totara (treated).
Heart matai – Dressing grade and matai (treated).
Heart tanekaha – Dressing grade and tanekaha (treated).
Heart kauri – Dressing grade and kauri (treated).
Heart rimu – Dressing grade and rimu (treated).
Radiata pine – Factory grade (treated).

(3) *For sills*

Timbers suitable are:
Heart matai – Dressing grade.
Heart tanekaha – Dressing grade.
Heart totara – Dressing grade.
Heart rimu – Dressing grade.
Heart kahikatea – Dressing grade.
Heart kauri – Dressing grade.
Heart red beech – clear grade.
As grades suitable for building have not been formulated yet for a number of timbers it is usual to ask for the equivalent of established grades of rimu or radiata pine.

Chief timber trees of New Zealand (Indigenous)*

The following is a description of the principal native forest trees and their distribution.

Softwoods

Name of tree	*Height in feet*	*Distribution of species*	*Description of timber*	*Uses of timber*
Kauri *(Agathis australis)*	80—150	Lowland forest of North Island from extreme north to latitude 38°	Even-textured, strong, durable, and easily worked. Does not warp during seasoning and has non-tainting and non-staining properties	Vats and churns for foodstuffs, pattern-making, boats. Uses of kauri largely limited by supply
Rimu or Red Pine *(Dacrydium cupressinum)*	60—110	Through the three islands	Straight-grained, workable, often figured. Sapwood soft. Heartwood fairly hard and strong. Easily split	Principal commercial timber. Building, furniture, joinery, panelling, plywood, and general purposes
Matai or Black Pine *(Podocarpus spicatus)*	40—80	Lowland forests throughout New Zealand Rare in Stewart Island	Straight, heavy, brittle, easily worked, strong, easily split, fairly hard	Weatherboarding, sills, flooring, palings, plywood
Totara *(Podocarpus totara)*	40—100	Lowland and montane forests of North and South Islands	Straight-grained, easily split, easily worked, fairly soft, stable, brittle, resists marine borers	Joinery. Formerly used for posts, rails, piles, sleepers, and general building. Limited by supply
Kahikatea or White Pine *(Podocarpus dacrydioides)*	80—120	Dominant in lowland and semi-swamp forest, North and South Islands	Tough, compact, straight, soft, easily worked, inodorous, clean	Tallow casks, butter boxes, battens, sink tops, turnery
Miro *(Podocarpus ferrugineus)*	50—80	Lowland forests throughout New Zealand	Strong, hard, compact, straight, fine-grained, workable, heavy	Suitable for same purposes as rimu from which it is not commercially distinguished

Hardwoods

Red Beech *(Nothofagus fusca)*	60—100	Lowland and montane forests south of latitude 37°. Throughout South Island	Strong, compact, hard, tough, more durable than other beeches, easily split	Suitable for same purposes as silver beech. Also posts, firewood, mine props, furniture, stringers for bridges and buildings.
Silver Beech *(Nothofagus menziesu)*	60—100	Lowland and montane forests south of latitude 37°. Plentiful in Southland	Straight, strong, tough, workable, compact	Furniture, bent woodwork, dowelling, motor bodywork, box timber, handles. Export
Tawa *(Beilschmiedia tawa)*	40—80	Lowland and montane forest of North Island, Marlborough, and Nelson	Straight-grained, easily worked, rather hard, brittle, easily split	Flooring, furniture, clothes pegs, boxwood, caskets, linings.

* *Native to New Zealand as distinct from exotic. Exotic trees are trees grown in New Zealand that are native to other countries.*

Chief exotic timber tree

Radiata pine *(Pinus radiata* Syn. *Pinus insignis)*	100—160	Native of California. Grown extensively in New Zealand afforestation schemes.	Soft, light, nails well, fairly tough and strong, clean and straight if well grown	General building timber, formwork, boxwood. Preservative treatment required where any likelihood of dampness. Export, plywood. Second only to rimu in commercial importance

Note: In afforestation schemes throughout New Zealand, apart from radiata pine, there are plantations of other softwoods; important ones being:
European larch, Douglas fir (oregon pine), Corsican pine, macrocarpa, lodgepole pine and Pinus elliottii (slash pine).

Timbers imported for buildings

Timbers of many kinds are imported into New Zealand for the various woodworking trades but those most commonly used by the building trade are listed below.

Name of tree	*Origin*	*Description of timber*	*Uses of timber*
Oregon or Douglas Fir *(Pseudotsuga taxifolia)*	North America	Timber has prominent annual rings, varies in colour from red to yellow and even nearly white. Very fair durability	Roof and general framing, beams, joists, and structural work where strength and resilience are required.
Redwood or California Redwood *(Sequoia sempervirens)*	North America	Timber is red-brown in colour, light in weight, soft, brittle, and very durable	Sashes, doors, and weatherboards. *Note:* Redwood should be fixed with galvanised nails or screws.
Western Red Cedar or Arbor-vitæ *(Thuya plicata* Syn. *T. Gigantea)*	North America	Timber is light in weight, dull reddish-brown in colour, very soft, brittle, easily split, and durable	Suitable for any purpose where a soft, light, durable but not strong timber is required such as for sashes, doors, and weatherboards.
Jarrah *(Eucalyptus marginata)*	Australia	Timber has great durability, beauty of texture and colour; and easy working. Red colour and of medium hardness	Owing to its durable nature it is suitable for outdoor work, decking, flooring, paving blocks, etc. *Note:* Jarrah should be fixed with galvanised nails or screws.

Questions on Chapter 3

(1) Make sketches of the cells in:
(a) Hardwoods.
(b) Softwoods.
Write a brief outline of the function of each type.

(2) Describe the growth process of some common tree.

(3) How are logs sawn into boards?
What is (a) Flat-sawn timber?
(b) Quarter-sawn timber?

(4) (a) Describe the term "relative humidity" and show how the relative humidity of the atmosphere affects timber.
(b) What would be a suitable moisture content for joinery timber?

(5) In connection with the shrinkage of timber;
(a) When does shrinkage commence?
(b) Why are the effects of shrinkage visible?
(c) Show by sketches how differential shrinkage affects sawn timber.

(6) Why is timber seasoned?

(7) Compare the advantages and disadvantages of:
(a) Kiln-seasoned timber.
(b) Air, or natural, seasoning of timber.

(8) Describe the various methods of seasoning timber:
(a) On the average building job.
(b) In a joinery establishment.
(c) In a sawmill timber yard.

(9) Explain briefly the causes of timber rot in New Zealand. Give two examples of poor building construction likely to cause conditions favourable to decay.

(10) Name three groups of wood preservative and describe the methods of application that are used in each case.

(11) (a) What is a blemish? Describe two blemishes you have found to occur most frequently in building timbers.
(b) What is a defect? List three defects.

(12) Name the kind, quality, and grade of indigenous timber you would use for each of the following members in a house:
(a) Sleepers.
(b) Wall plates.
(c) Floor boards.
(d) Rafters.

(13) What is meant by "running feet" and "foot B.M."

(14) Draw a cross section of a Pinus radiata log, naming the various parts shown. Write notes describing the function of three of these parts.

(15) Show how a 12 in. x 2 in. piece of timber would warp when the annual rings are:
(a) At an angle of less than 45° to the face of the timber.
(b) At an angle not less than 45°.

(16) What precautions are taken to protect buildings against termite attack?

(17) What is the life cycle of the Australian termite?

Calculations

(1) How many ft. B.M. are in the following timber list:
(a) 897 ft. linear of 6 in. x 1 in. timber.
(b) 576 ft. linear of 6 in. x 2 in. timber.
(c) 875 ft. linear of 10 in. x 2 in. timber.
(d) 1,050 ft. linear of 12 in. x 8 in. timber.

(2) How many feet linear are in the following timber list:
(a) 6 in. x 1 in. timber – 1,050 ft. B.M.
(b) 5 in. x 2 in. timber – 786 ft. B.M.
(c) 9 in. x 2 in. timber – 1,387 ft. B.M.
(d) 12 in. x 3 in. timber – 923 ft. B.M.

(3) Calculate the number of ft. B.M. and the total cost of the timber at 78s. per 100 ft. B.M. in the following timber order for a small building:

137 ft. linear of 4 in. x 3 in. sleeper plates.
276 ft. linear of 4 in. x 2 in. wall plates.
1,280 ft. linear of 4 in. x 2 in. studs.
768 ft. linear of 5 in. x 2 in. floor joists.
400 ft. linear of 12 in. x $2\frac{1}{2}$ in. floor joists.

(4) A sample of timber, after being dried in an oven, weighs 5·64lb. After being left in the open it is found to weigh 6·183 lb. What is the increase of weight due to the absorption of moisture expressed as a percentage of the dry weight?

(5) What will be the finished width of a board that is 12 in. wide when cut from a log, if it shrinks $\frac{3}{8}$ in. in width during seasoning and each edge is reduced $\frac{3}{16}$ in. during dressing?

Chapter 4

FOUNDATIONS

Survey of site

Before a building is planned the site must be inspected and the following points considered:

(1) Type of soil and subsoil – rock may be encountered, which would materially affect the cost of excavation work. (This information is also required by the local authority, to be given on the building application.)

(2) Clearing of the site – large trees may have to be felled.

(3) Slope of the ground – this may involve high foundation walls.

(4) Draining or raising of level of ground – low-lying places may need draining and possibly filling, while in other cases extensive excavations may have to be made.

(5) Distances from building site of services such as water, sewers, and electricity.

Legal description of site

It is not always sufficient to take the word of a property owner that a particular piece of land is his section; the markings on survey pegs must be checked with the legal description of the property, which may be obtained from the title deeds of the property or the subdivision plan at the local authority's office.

Survey pegs (*Fig.* 93)

Survey pegs, usually of 3 in. x 2 in. heart totara 21 in. long, are found projecting 3 in. or 4 in. above ground at the corners of sections. The sides of the pegs are marked with section numbers cut in the wood. On a road line the peg has the letter 'R' cut in it. To mark the exact point of intersection of boundary lines at a corner, a copper tack is driven in to the top of the peg.

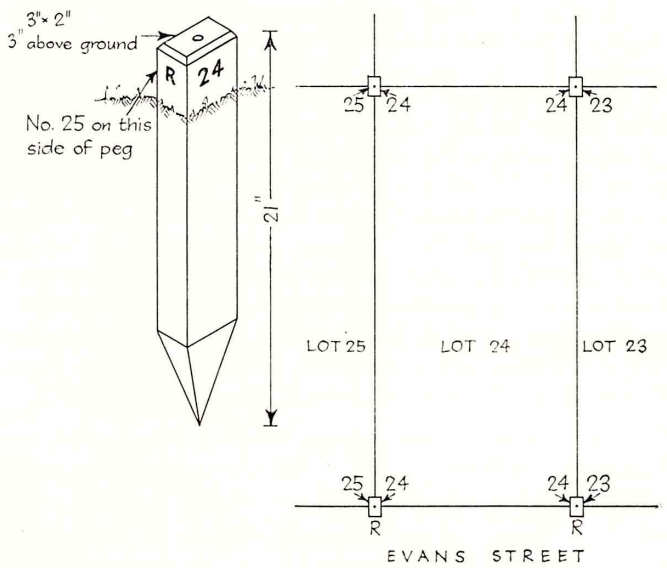


Fig. 93

Typical site plan

In a new subdivision the survey pegs are usually located easily, but in old subdivisions the pegs may have vanished so that a redefinition of the boundaries must be made by a registered surveyor.

Fences about properties are not always in their exact positions; so when a building is to be erected near to or against a boundary, it is best to have a surveyor define the exact boundary rather than site the building incorrectly.

Principles of setting out foundations

The first important step in the erection of a building is to locate the foundation accurately on the section. The whole process can be carried out with a level, plumb-bob, measuring tape, straight edge, and by the use of profiles, pegs, and lines. The problem resolves itself into four parts:

(1) The location of the line on which the front of the structure must lie.

(2) The location of the corners of the front of the structure.

(3) The setting out of the line along the side of the structure at right angles to the original line.

(4) The location of all other lines, these usually being parallel, either to the original line, or to the line at right angles to it.

Setting out a right angle

The setting out of a right angle between two lines of considerable length cannot be accomplished with any degree of accuracy with an ordinary large steel square; so the usual method is to obtain a right angle by the use of the 3 : 4 : 5 rule.

Assuming a line AP (*Fig.* 94) a distance of 3 ft. is measured from A to B. Along AR at approximately right angles to AP a distance of 4 ft. is measured from A to C. The line BC of the triangle so formed will measure exactly 5 ft. if the angle CAB is a right angle. All that is necessary is to adjust the line AR from point A until the point C coincides with the 5 ft. graduation mark along the hypotenuse from B. Any multiples of 3 : 4 : 5 may be used to obtain a similar result and the distances 6 : 8 : 10 and 12 : 16 : 20 are commonly used. The 3 : 4 : 5 rule may be stated thus:

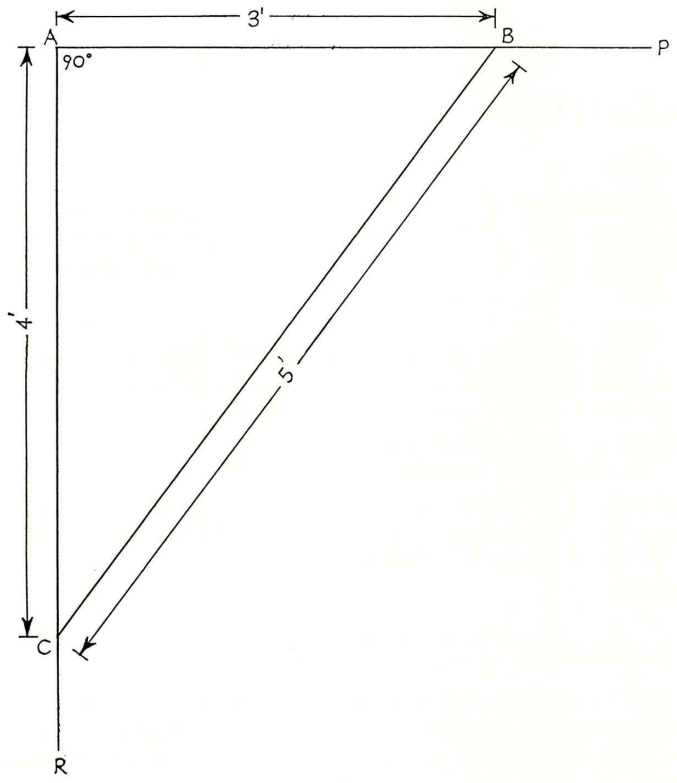


Fig. 94

3:4:5 method of forming a right angle

To lay out a right angle, measure out the adjacent sides of a right-angled triangle 3 units long and 4 units long respectively and adjust the angle between these lines until the hypotenuse is 5 units long.

Profiles (*Fig.* 95)

Profiles are temporary guides of 6 in. x 1 in. boards 2 to 3 ft. long fixed horizontally to stakes driven in the ground. The profiles should be about 3 to 4 ft. away from the actual foundation. Once the building lines have been located, their positions should be permanently marked on the top edge of a profile by means of partially driven nails or saw cuts in the boards. The top edges of all profiles are made level one with another.

Fig. 96 shows a profile with the position for building lines of a foundation wall shown by vee cuts in the top edge of the profile.

Setting out a foundation

In our discussions on setting out a foundation we shall refer to the rectangular building on the irregularly shaped section shown in *Fig.* 97.

Minimum distance from boundaries

The minimum distance between a building and section boundaries or other buildings is covered by building by-laws, and reference should be made to the particular bylaw on the point. Bylaws vary in different districts, but for our purposes let the distances as shown in *Fig.* 97 be regarded as minimum distances from boundaries at the front and the side of the building.

Reference lines

Sections are frequently irregular in shape and are not always at right angles to the roadway. In such cases either the road line or a side boundary line may be used as the first reference or setting-out line, depending upon whether the proposed building is to be parallel to the street or the side boundary. In this instance the road or front boundary of the section will be used as the first reference line.

The setting out procedure is as follows:

(1) Stretch a line AB (*Fig.* 97) between the points indicated by tack heads on the two front survey pegs.

(2) Stretch another line LM parallel to and 25 ft. from AB. One line is made parallel to another by measuring their distance apart at an angle of 90° from the ends of the original line. An arm of a steel square is held to the original line and a steel tape stretched parallel to the other arm of the square. The new line is fixed to pegs driven at the required distance. This line represents the front line of the building and the stakes supporting it should be 1 ft. to 2 ft. out of the ground.

(3) Drive a stake at E, 4 ft. from the side boundary and another at F, making EF the width of the front of the building. On the top of each stake a tack or nail must be driven to indicate the exact point of measurement. The profiles 1 and 2 (*Fig.* 95) may now be set up and the front line transferred from the stakes to the profiles for permanence.

(4) The next operation is to set up the line FD at right angles to the front line EF. This is done by the 3 : 4 : 5 method. Using the ratio 12 : 16 : 20, on line EF and 12 ft. from F drive a stake and mark the exact point G with a nail in the top of the stake. Erect a temporary platform on line FD, the centre of which is about 16 ft. from F. With the end of steel tape stretched from the nail at F, pencil in an arc OP on the platform, 16 ft. from F. From the nail at G stretch a steel tape and, at the 20 ft. graduation mark, pencil in an arc on the platform intersecting the previous arc made. At the point of intersection of the arcs, K, partly drive a nail. Set up profiles 3 and 4 and stretch a line from profile 3 through points F and K and attach the end of the line to profile 4.

(5) The profiles 5 and 6 may now be set up and line CD made parallel to EF. Line EC is similarly made parallel to line FD and fixed on profiles 7 and 8.

(6) The lengths of the diagonals should be checked by measuring FC and ED. If the angles are right angles the lengths of these diagonals will be equal.

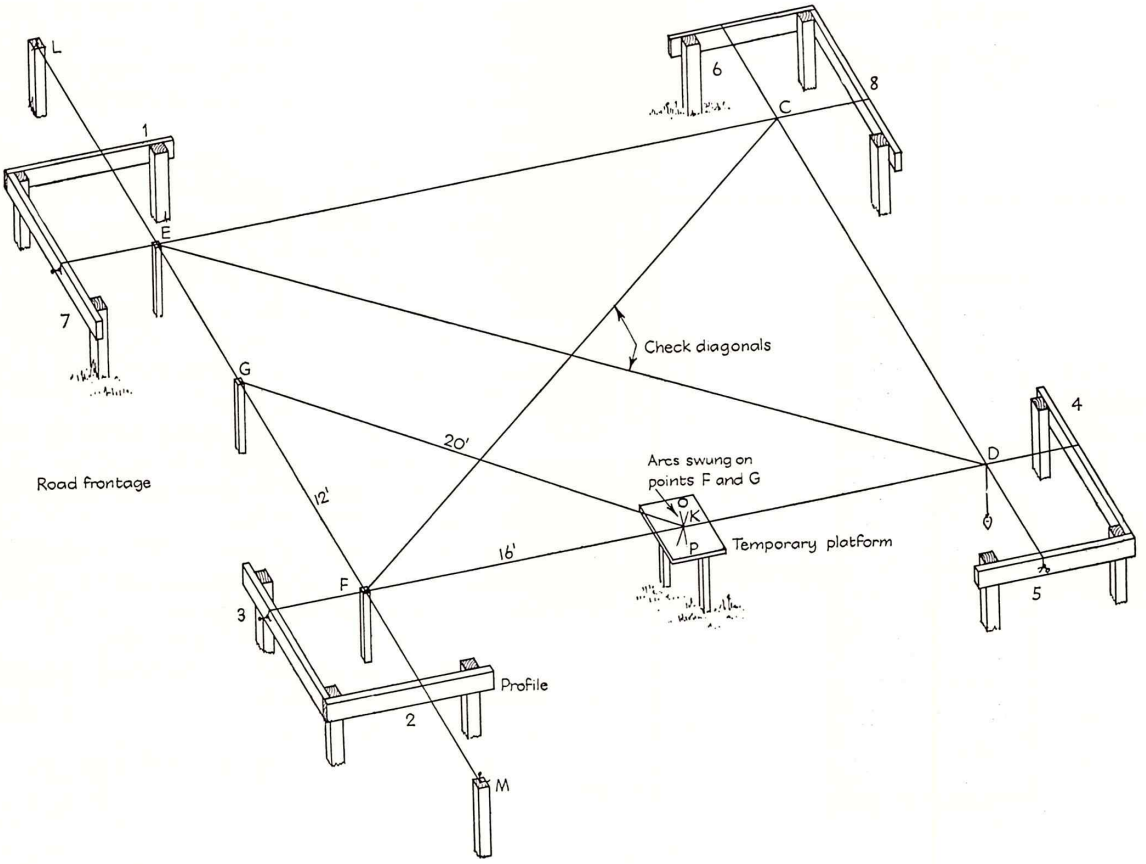


Fig. 95

Setting out of profiles and reference lines

Setting out offsets

When a plan is not in the shape of a complete square or rectangle but has offsets, the layout procedure is identical with the methods described above. Additional profiles will be required for the offsets, but all measurements for the setting up of these profiles may usually be taken from the main setting-out lines, as the lines marking the offsets will be parallel to them.

Alternative method of setting out

Frame method

In this method profiles are not used; this means a saving of time, but on the other hand the method cannot be used on other than flat sections.

A wooden frame to the plan shape of the building is made as follows:

To represent the first building line a 6 in. x 1 in. is laid on the ground, straightened, and securely staked. Other 6 in. x 1 in. timbers are then laid down to the shape of the building with any offsets included or omitted temporarily.

The rectangle or square now formed, with one side fixed to the ground, is racked until the diagonals are equal so that all angles are right angles. It is now pegged at the corners and the sides straightened in the usual way.

Any errors in length due to fall will be slight and may be corrected when the wall plates are set out.

The 6 in. x 1 in. timbers serve not only as a guide for the excavation of foundation trenches but also as ground plates for the formwork.

Setting out with builder's level

The builder's level (*Fig.* 98)

The builder's level in its simplest form consists of a telescope and levelling attachment which can be rotated

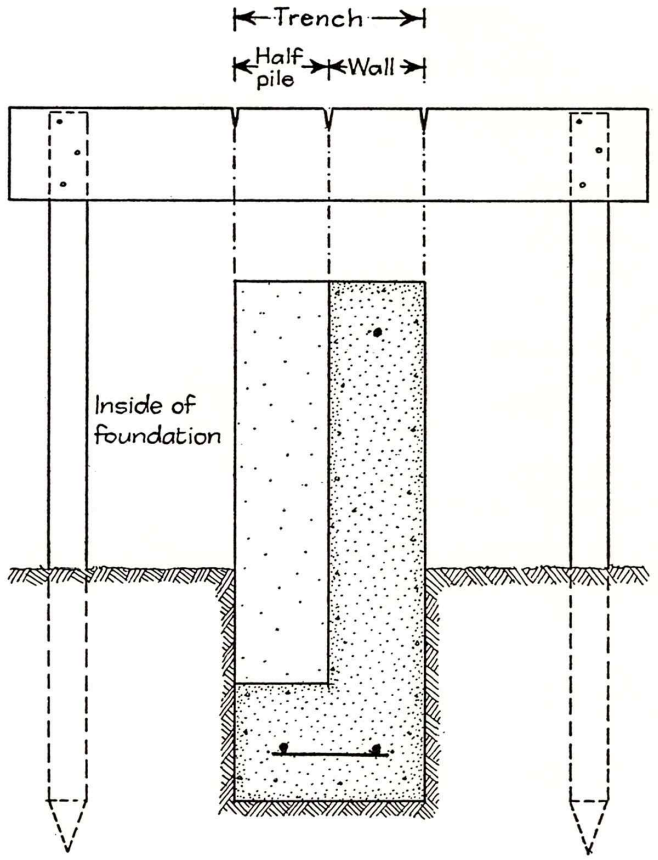


Fig. 96
Marks (cuts shown) on a profile for a brick-veneer foundation wall

through 360 degrees in a level plane. It can be used either mounted on a tripod with telescopic legs or placed without the legs on some flat rigid surface, the level being set up outside the job or near the centre of the job and the levels checked as the work proceeds.

The plumb rule (Fig. 98)

This rule is used in conjunction with the level to locate positions below the line of sight. It is held in a vertical position and moved across the line of sight until the plumb line of the rule coincides with the vertical cross hair of the telescope.

Adjustment and use of a modern type of builder's level

Having set up the stand and firmly secured the instrument on it by the centre attachment screw, the tripod legs are moved until the plumb-bob is directly over the reference mark or nail. To adjust and use the level carry out the following movements:

(1) Slacken the clamping ring and then, by moving the instrument on the ball and socket joint, get the circular bubble approximately level. Tighten the clamping ring.

(2) Sight the telescope on to a plumb-rule held vertically above a reference point, focus by means of the milled head focusing screw, and bring the main bubble to the middle of its run by screwing the tilting screw up or down. Lock the telescope in this position. By means of the slow motion screw bring the vertical cross wire in the telescope directly in front of the plumb line of the plumb rule.

(3) Move the graduated circle (*Fig.* 99) around until the zero mark on it coincides with the zero marker.

(4) Release locking screw and turn the telescope through 90° until the zero marker coincides with either the 90° or the 270° mark on the graduated circle. The zero marker will coincide with either the 90° or 270° mark, depending upon whether the telescope has been turned to the right or to the left. This is shown in *Fig.* 99.

(5) Focus the telescope and bring the main bubble to a level position by turning the tilting screw. (Every time the telescope is moved it must be brought level again by turning the tilting screw.)

(6) The line of sight is now at 90° to the original line of sight, and this can be transferred to a peg in the ground by means of a plumb-rule.

The carpenter uses a builder's level for:

(1) Levelling foundations of a building and maintaining levels as the work proceeds.

(2) Finding levels generally.

(3) Setting out right angles of foundations, etc.

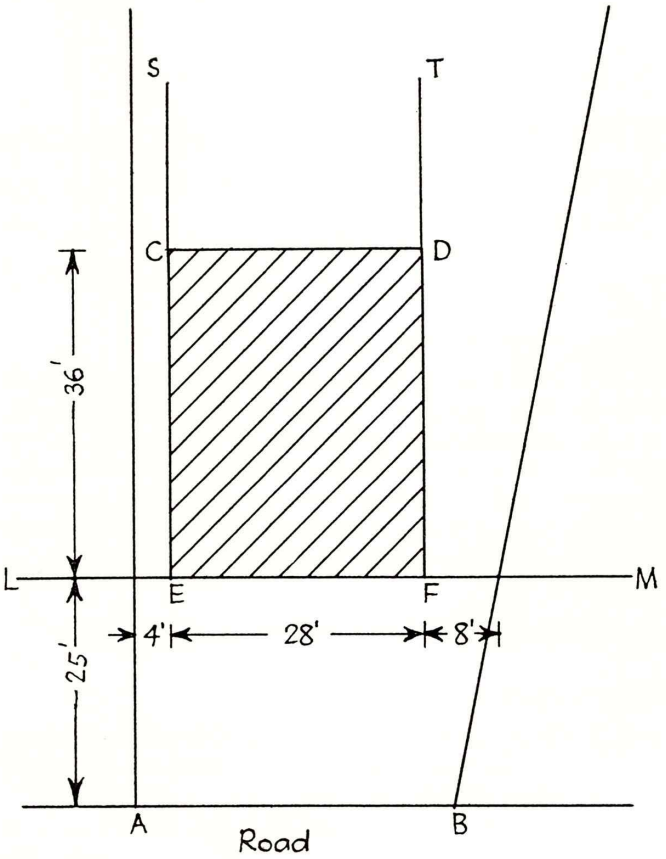
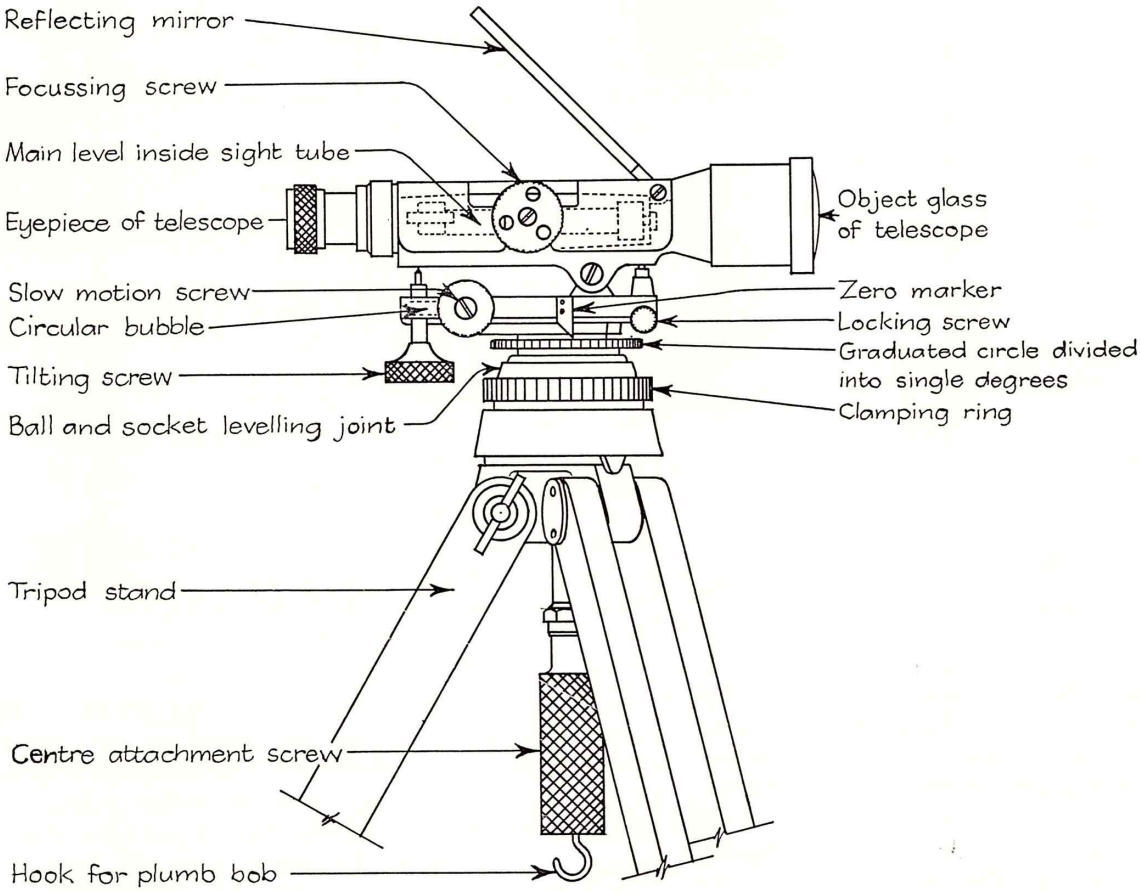
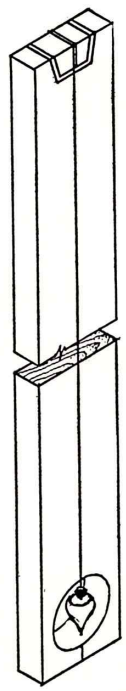


Fig. 97
Setting out of a building





Plumb Rule

Fig. 98 *Builder's level and plumb rule*

Setting out with a builder's level (*Fig.* 100)

The use of a builder's level, to set out the building lines shown in *Fig.* 97 will be described, commencing after the pegs E and F have been fixed.

(1) Set up the level above peg E so that the plumb-bob is directly above this point, and sight the telescope on F; set the graduated circle at zero, swing the telescope through 90°, sight to the plumb-rule held at S, adjust, and drive a peg vertically in line. Stretch a line between S and E. Measure the length CE with a steel tape and drive in peg C.

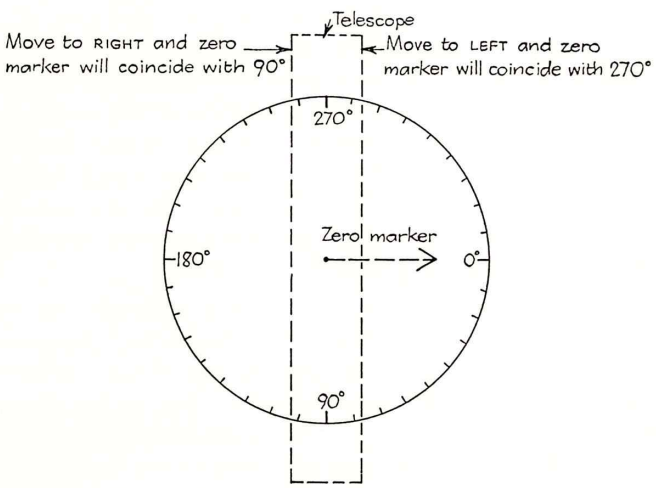


Fig. 99

Graduated circle (degree dimensions not shown)

(2) Move the instrument to peg F. Sight the telescope on peg E. Set the graduated circle at zero, swing the telescope through 90°, sight to the plumb-rule, adjust, and drive the peg T vertically in line.

Measure the length FD with a steel tape and drive the peg D.

(3) Set up the instrument at D and sight the telescope on peg F; set the graduated circle on zero and then swing the telescope through 90° to locate peg C at the intersection with the line SE. The length of EC should equal FD, and CD be equal to EF.

Offsets are set out in a similar manner to that just described.

The builder's level need not be used at every corner of the building to determine a right angle. Provided a right angle is determined at one corner only, the remainder of the setting out may be done by measurement as described previously in this chapter.

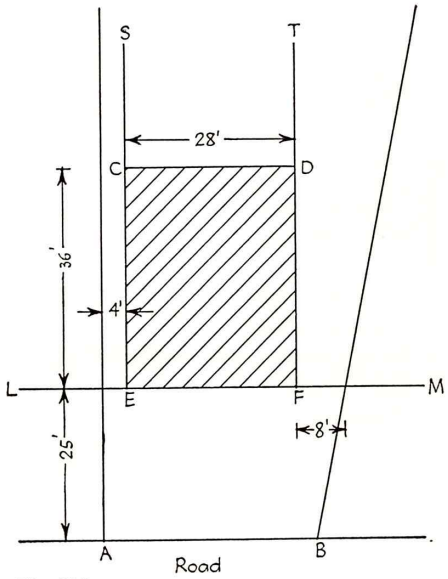


Fig. 100
Setting out with a builder's level

Levelling with a builder's level (*Figs.* 101, 102)
Levelling is the operation of determining the vertical heights above or below some horizontal plane adopted as a datum, this being an assumed line or level surface from which heights and depths of surfaces are reckoned.

Datum peg
A datum peg is a peg or stake driven on or about a building site from the top edge of which heights or depths are measured. The top edge of one particular profile is commonly used as datum and the top edges of all profiles are then kept level with it.

Levels for a building
When the profiles and the setting out of the foundation have been completed the formwork for the concrete foundation walls may be commenced. The depths of excavations and heights of walls, reinforcing steel, sleeper plates, vent boxes, porch floors, and copper slabs, etc. may be measured from the datum peg or datum line with the aid of the builder's level.

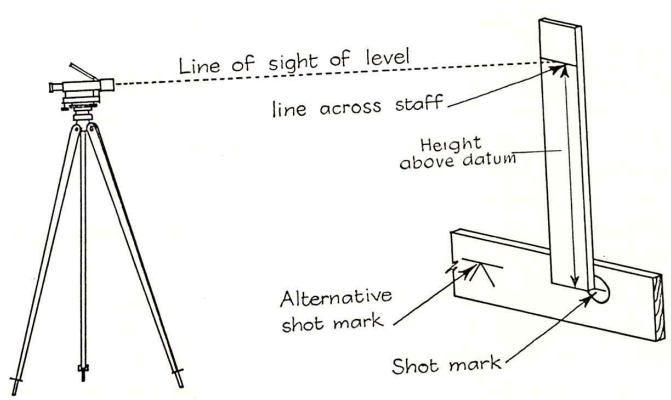


Fig. 101 *Method of levelling*

The level is set up on its tripod, or on the top of a post inserted for the purpose near the centre of the building, and when the instrument has been levelled, the structure may be checked in a level plane through 360° by rotating the telescope and taking observations or sights where required.

Sights are made to a staff (*Fig.* 102) held vertically on the datum or at any other point. The surveyor's staff is graduated in feet and hundredths of a foot, but other types are graduated in feet, inches, and eighths of an inch. When a staff is not available, a rod marked in feet, inches, and eighths of an inch may be used on reasonably level sites, or a carpenter's rule may serve the purpose. On a sloping site the use of a proper staff is advised.

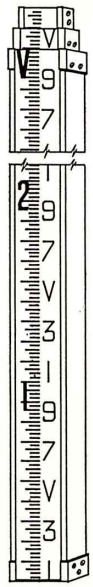


Fig. 102
Levelling staff

In taking levels, first drive pegs in the ground at all points which are to be levelled. Direct an assistant to hold the staff or marked rod at the point which is to be the datum level and to which all other points are referred. Sight the telescope on the rod and after checking the level bubble to the centre of its run, read the division on the rod which is cut by the central horizontal line in the telescope. Suppose this reads 2 ft. 3 in. Direct the assistant to place the rod on another position to be levelled with the datum position, again check the bubble for level, and sight the telescope on the staff. If it should read 2 ft. 2 in. the new point is 1 in. higher than the datum level. The peg should therefore be driven until the reading is the same as that on the datum position, i.e., 2 ft. 3 in. Instead of driving pegs as described, the datum may be marked on the formwork at various places by a horizontal line known as a shot mark. A shot mark is shown by a circle with a horizontal line across it, with a nail marking the centre, or it may be shown with a horizontal line touched by a V-mark with a nail driven at the point of the V (*Fig.* 101). Blue is the commonest colour for datum marks and yellow is usual for marking positions of reinforcing steel.

The heights of the various parts of a building may be marked either above or below the datum line. Suppose the datum line corresponds with the top of the concrete foundation wall, and assuming that this is 2 ft. 3 in. below the line of sight, the top of the reinforcing steel will be 2 ft. 4 in. below, and the level of the top of the 4 in. sleeper plates will be 1 ft. 11 in. below the line of sight.

Levelling with straight edge and carpenter's level

Levels may be made with a carpenter's spirit level and a straight edge. Commencing from the datum, the straight edge is levelled from point to point around the building and back to the datum as a final check. In levelling, the straight edge and level must both be reversed in direction at each step of the process to minimise any inaccuracies of the level.

Foundations — timber-framed buildings

Foundations are walls, blocks or piles which transmit the weight of a structure to the underlying ground.

Footing

The "footing" is the lower part of a foundation wall which rests on the excavated surface as shown in *Fig.* 103A. A "spread footing" (*Fig.* 103B) is the lower part of a foundation wall resting on the excavated surface, enlarged in order to distribute the load over a greater area.

In modern timber-framed buildings, concrete foundation walls are usually erected without any increase in width at the base of the wall. Where such buildings are erected on poor ground or are of greater weight, e.g., brick veneer, "spread footings" must be used. These footings are of reinforced concrete laid upon the earth at the bottom of the excavation and form part of the foundation wall.

Ground-floor supports

Ground-floor supports include all parts of the frame above the foundations which directly or indirectly support the ground floor (i.e., dwarf walls, sleepers, joists).

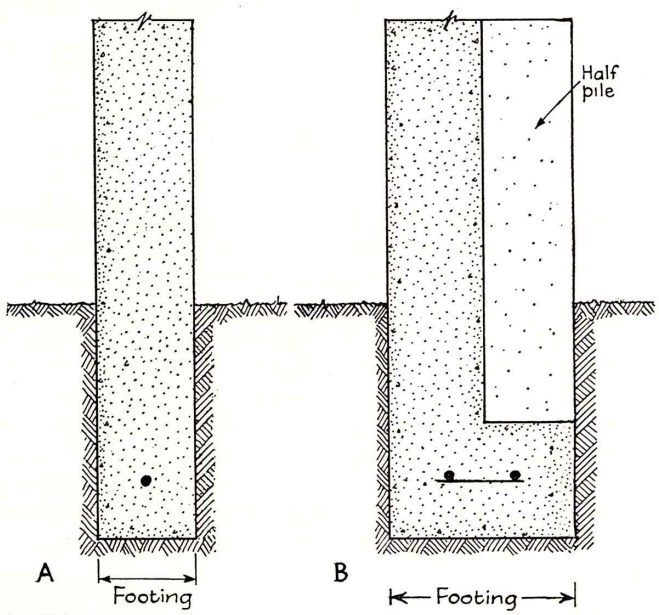


Fig. 103

Concrete foundation walls

(A) *Section of concrete foundation wall*
(B) *Section of concrete foundation wall for a brick-veneer wall*

Dwarf walls (*Fig.* 104) are walls of timber, plates, studs, and braces, or 5 in. reinforced concrete or 9 in. brickwork, and are used to support ground-floor joists more than 4 ft. 6 in. above ground level.

Types of foundations

Foundations can be divided into either internal or external structures.

Internal foundations in most cases consist of piles, if their height does not exceed 4 ft. 6 in., and of dwarf walls if they would exceed this height. Regulations dealing with pile foundations are referred to later.

External foundations, supporting the outside walls, are of varied design as follows:

(1) Blocks or piles of concrete or other approved material.

(2) Piles and reinforced concrete corner walls.

(3) Continuous walls of brick, stone, or concrete.

(4) Concrete floors combining both internal and external foundations.

(1) *Pile foundations*

Many buildings are built entirely on piles. Where piles under external walls are on the average *more* than 2 ft. 6 in. out of the ground the piles must have 4 in. x $1\frac{1}{2}$ in. walings fixed by $\frac{1}{2}$ in. bolts on each side at 6 in. above ground level. Such walings must be of heart quality or preservative-treated to the approval of the Timber Preservation Authority. Between the two end piles a 4 in. x 3 in. brace must be fixed between walings and sleeper plate (*Fig. 105*A).

In rows of internal piles similar walings and braces must be fixed at intervals of 16 ft. in each direction, if the piles are more than 2 ft. 6 in. out of the ground.

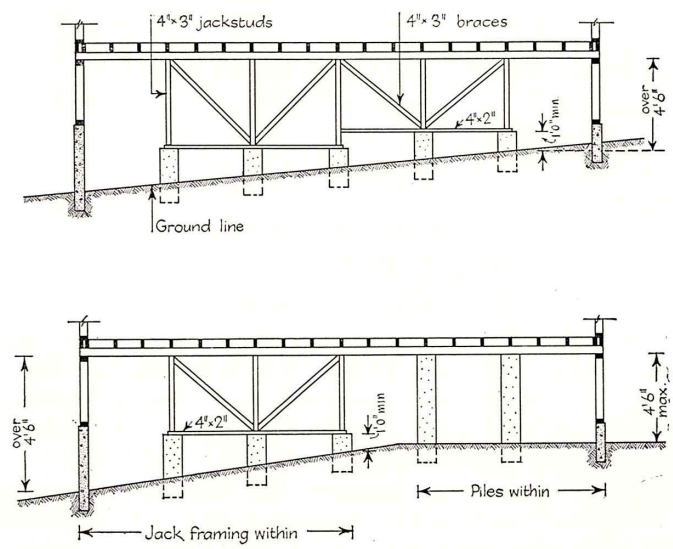


Fig. 104

Two methods of framing ground-floor supports

Alternatively the outer walings may be omitted if:

(1) $1\frac{1}{4}$ in. base boards are fixed (*Fig.* 105B).

(2) Concrete piles not more than 3 ft. 6 in. above ground have an 18 in. x 18 in. x 6 in. footing cast at the same time as the pile (*Fig.* 105C).

(3) The space between piles is filled in with brick, stone, or concrete panels, on a solid footing. The panels must have bonding or reinforcement and be tied to the piles (*Fig.* 105C).

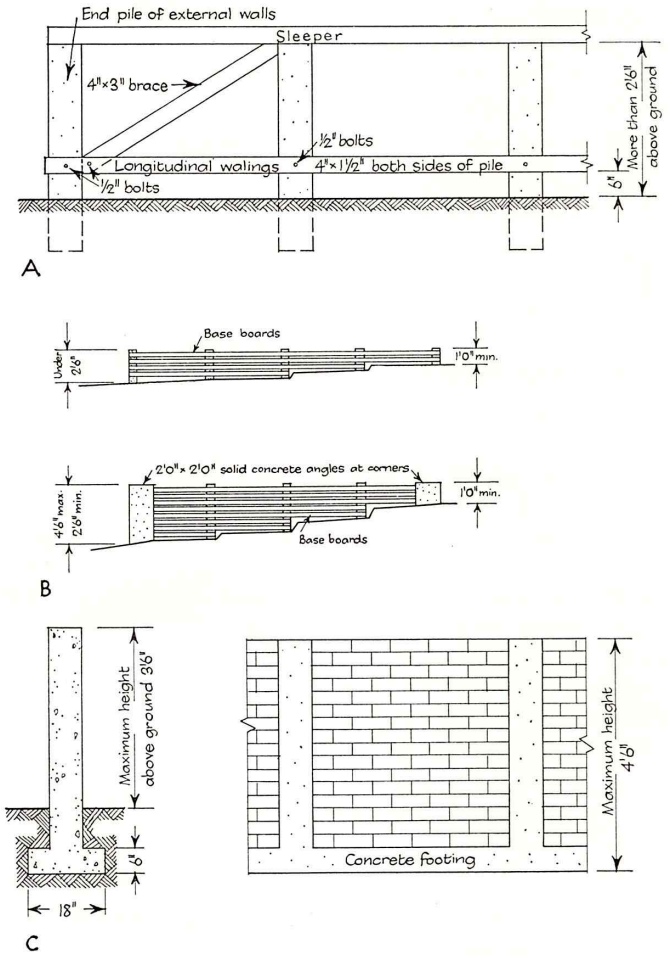


Fig. 105

Piles under external walls

(A) *Piles braced and tied with waling*
(B) *Piles tied with base boards*
(C) *Spaces between piles filled with brickwork*

In some districts foundation blocks of concrete are used, above which is a construction of timber jack framing. The regulations governing pile foundations are given in N.Z.S.S. 1900, Chapter 6.1. Under certain conditions timber piles may be used, but on most occasions piles are of concrete. Properly laid brick or stone piles are at times used instead of concrete piles, but the height of such piles must not exceed four times their least dimension.

Depth of piles (*Fig.* 106)

Piles must rest on a solid foundation at least 12 in. below ground level. Under certain conditions the local authority engineer may approve that the depth to which piles are sunk may be reduced.

Height of piles (*Fig.* 106)

Piles may not extend less than 6 in. or more than 4 ft. 6 in. above ground level.

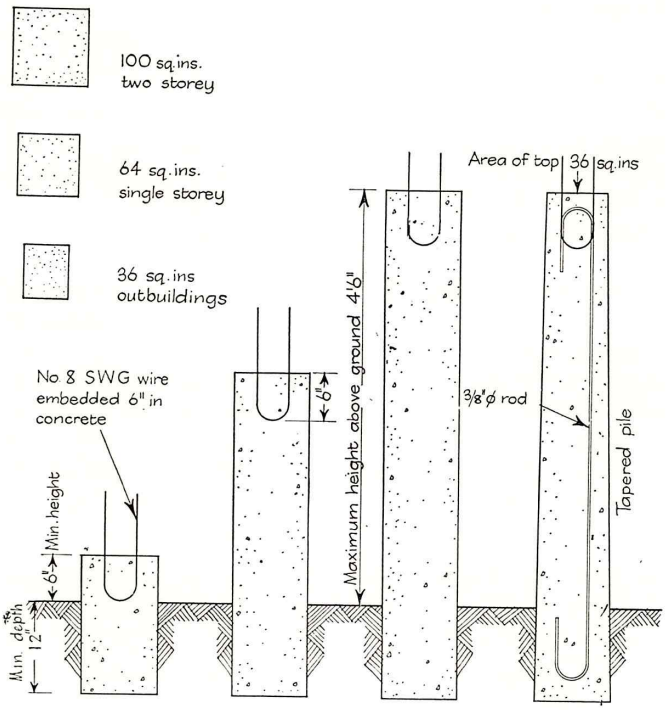


Fig. 106

Height, depth, and cross-sectional area of piles

Spacing of piles

Under wall or sleeper plates, piles should be equally spaced in rows at not more than 4 ft. 6in. centres, and when the rows are not more than 7 ft. centre to centre, the cross-sectional area of the piles should not be less than that given in Table 3. Minimum sectional areas of Foundation Blocks or Piles. N.Z.S.S. 1900, Chapter 6.1. When, however, the rows of piles are at a greater distance than 7 ft. centre to centre, the piles should be increased in sectional area by one-tenth for every 1 ft. or part of a foot in excess of 7 ft. Under a main bearing partition, a dwarf wall or row of piles should be directly under the line of the partition, or not more than 1 ft. from such line.

Concrete piles

Concrete piles may be either "cast *in situ*" (cast in place) or "precast".

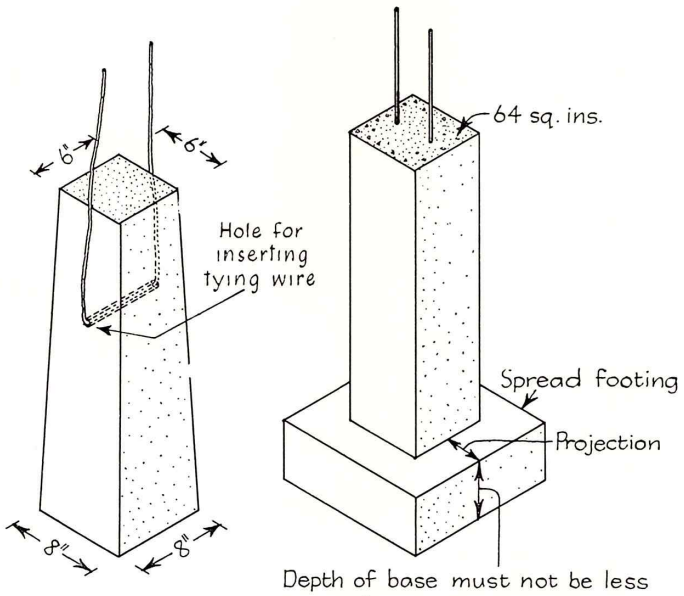

6"
6"
Hole for inserting tying wire
8"
8"
Tapered piles reinforced with a steel rod not less than ⅜"ϕ when longer than 2'6"
64 sq. ins.
Spread footing
Projection
Depth of base must not be less than 4" or double the projection

Fig. 107

Types of piles

For piles "cast *in situ*" a timber boxing is erected about the hole dug for the base of the pile, and the concrete is placed in the usual way.

Tapered piles (*Fig.* 107)

Concrete piles may be tapered from 8 in. x 8 in. at the bottom to 6 in. x 6 in. at the top, provided that, if they are more than 2 ft. 6 in. long, they must be reinforced with a steel rod of $\frac{3}{8}$ in. diameter.

Footings for piles (*Fig.* 107)

Where a greater sectional area than 64 sq. in. is required for a pile the area of the base only may be increased. Bases or footings must not be less than 4 in. in depth or double the projection of the base beyond the pile, whichever is the greater distance. Precast piles must be set in the base before it has set.

Piles on poor ground

When piles are on ground that will not safely sustain the load that it has to bear the bases of piles must be varied in area and depth to the requirements of the local authority engineer.

(2) ***Reinforced concrete corner walls*** (*Fig.* 108)

Sometimes instead of piles all round the exterior walls and in all cases on a sloping site where the bottom plate at more than one corner is more than 4 ft. above ground, continuous reinforced-concrete corner walls are constructed extending from each of such corners for a distance of not less than 4 ft. 6 in. along each adjacent wall.

The construction between the corner walls is made up of piles if the height above ground does not exceed 4 ft. 6 in., or dwarf walls when the height exceeds 4 ft. 6 in. Between the piles on external walls the spaces may be filled with reinforced concrete ($3\frac{1}{2}$ in. thick), brick or stone (4 in. thick). These panels must, of course, have a system of reinforcing which ties them to the piles and they must also have solid footings. Alternatively the spaces between the piles may be covered with either horizontal or vertical base boards.

The usual provisions must be made for the ventilation of the space under the floor.

(3) ***Continuous reinforced concrete foundation walls*** (*Fig.* 109).

On a comparatively level site the foundation walls of a building could be continuous walls of reinforced concrete, but when the site is sloping the continuous concrete walls may be stepped and extended in height by dwarf walls of timber-framed construction.

The following is a summary of the regulations dealing with continuous reinforced concrete foundations as found in N.Z.S.S. 1900, Chapter 6.1.

Depths of foundations (*Fig.* 110)

All foundations must rest on a solid bottom at least 12 inches below the adjacent ground.

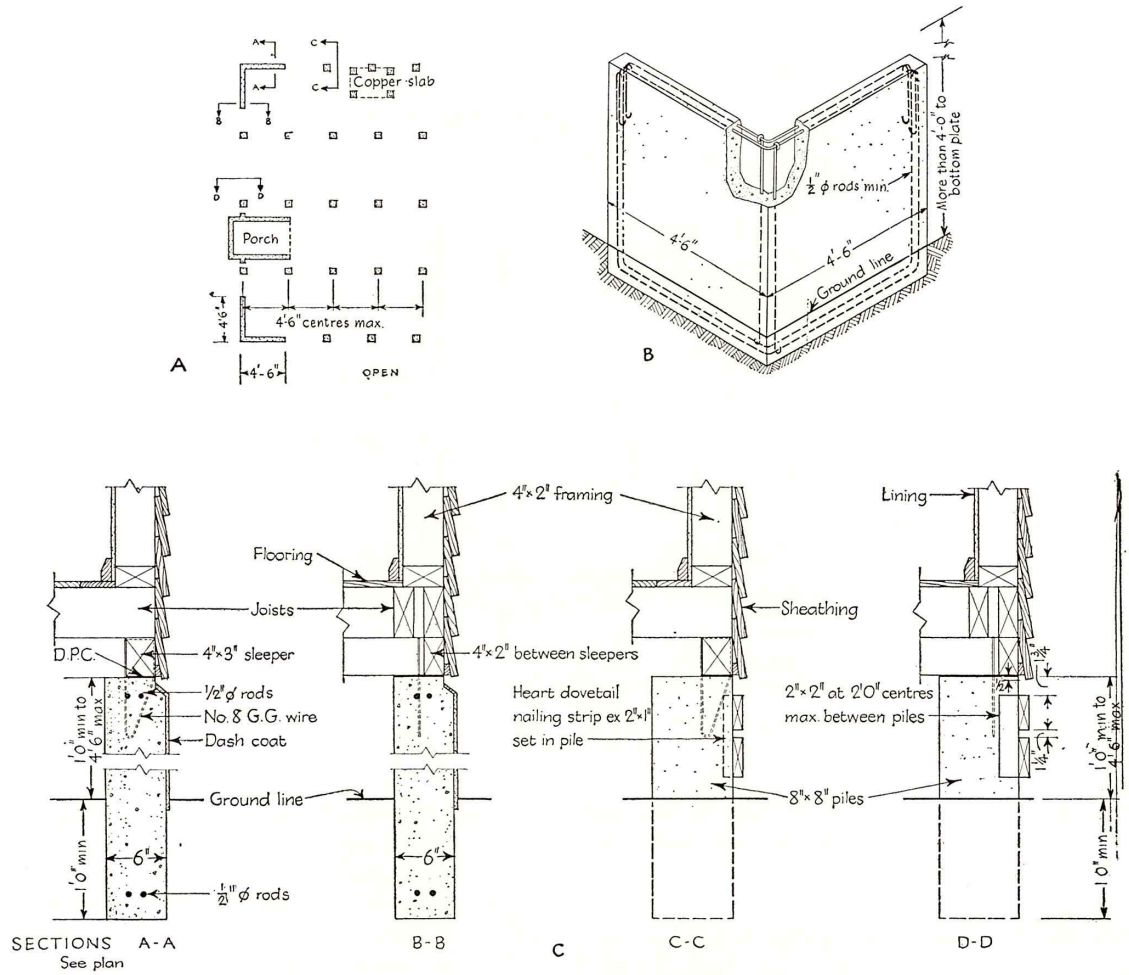


Fig. 108

Reinforced concrete corner-wall construction

(A) *Part of foundation plan of building showing corner-wall construction*
(B) *Isometric view of reinforcing steel of corner wall*
(C) *Cross sections of corner-wall construction*

Minimum height of foundation walls (*Fig.* 110)
Foundation walls must extend at least 12 in. above the ground and in any case sleepers must be that distance above the ground to:
(1) Ensure ample ventilation under the floor.
(2) Prevent dampness in the building.
(3) Provide space for inspection.

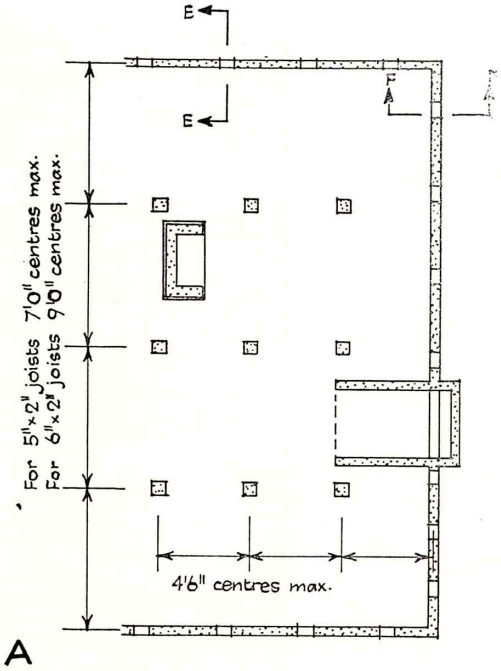
Thickness of foundation walls (*Fig.* 111)
Reinforced-concrete foundation walls for a one-storey building must be 5 in. thick and for two-storey buildings 6in. thick. Where, however, foundation walls exceed 6 ft. in height above the ground, as in the case of a basement, they must be considered as the walls of a lower storey of a two-storey building and made 6 in. thick.

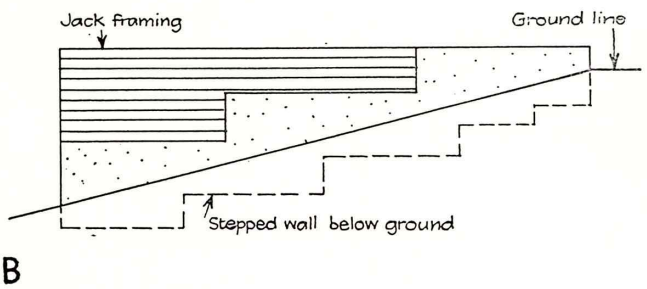
Bar and wire reinforcement (*Figs.* 111, 112)
The plans and specifications, or the local bylaws, describe the type, size, and spacing of the reinforcing steel for the foundation walls. (See N.Z.S.S. 1900, Chapter 6.1, Foundation Walls, and Footings.)

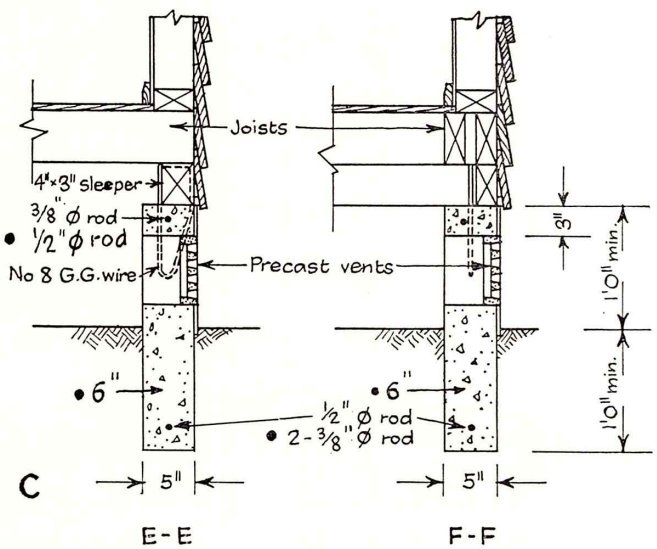
Protection of steel
Steel embedded in concrete must have sufficient thickness of concrete to protect it. This protective layer is known as "cover".

The amount of cover required is set out in Table 4 Concrete Cover of Reinforcing Steel, N.Z.S.S. 95, Part V.

Stepping of foundation walls and footings
The bottom and top of foundation walls must always be horizontal, and on a sloping site it becomes necessary to "step" the foundation. See *Fig.* 113. To provide extra strength these steppings must be overlapped in concrete for a length equal to the height of the step or 2 ft., whichever is the lesser measurement. All steel reinforcing must be continuous throughout the steps.







Continuous reinforced concrete foundation wall

(A) *Part of foundation plan of building with continuous walls of concrete*

(B) *Elevation of stepped foundation wall*

(C) *Cross sections through foundation wall*
(Reinforcing steel for two-storey construction indicated by large dots)

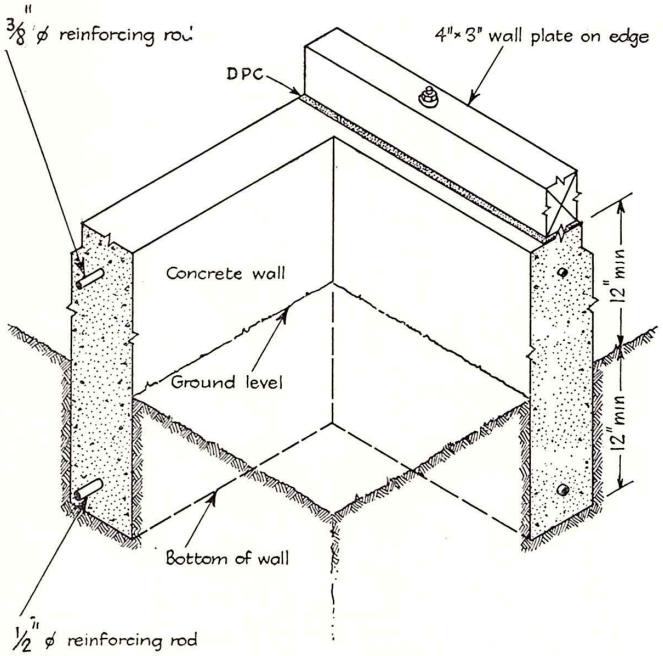


Fig. 110

Typical foundation wall
(Note minimum height above, and depth below ground level)

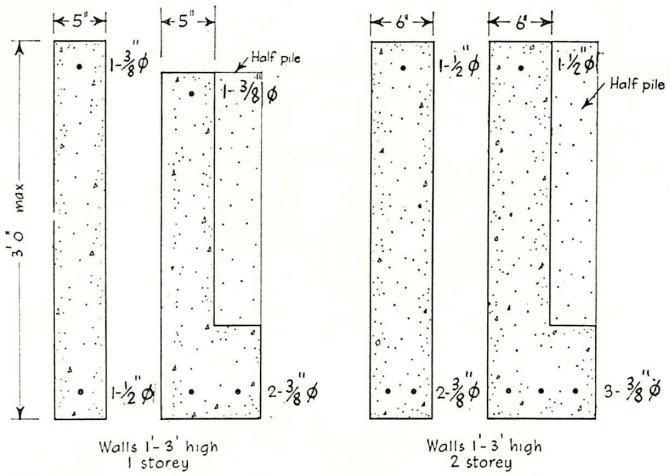


Fig. 111

Typical arrangement of reinforcing steel for continuous concrete foundation walls 1 ft. to 3 ft. in height

Ventilation of under-floor space

When the exterior foundation walls of a building are of concrete a system of cross ventilation is usually arranged by placing vermin-proof precast concrete ventilators into openings previously cast in the exterior foundation walls. These ventilators are evenly spaced at intervals of not more than 6 ft. commencing 2 ft. 6 in. from corners, and are placed as near as possible to wall plates. (See *Fig.* 114.)

Termite proofing

The termite proofing of buildings by fixing metal shields to foundation walls, concrete floors and piles is fully dealt with in Chapter 3 – Timbers.

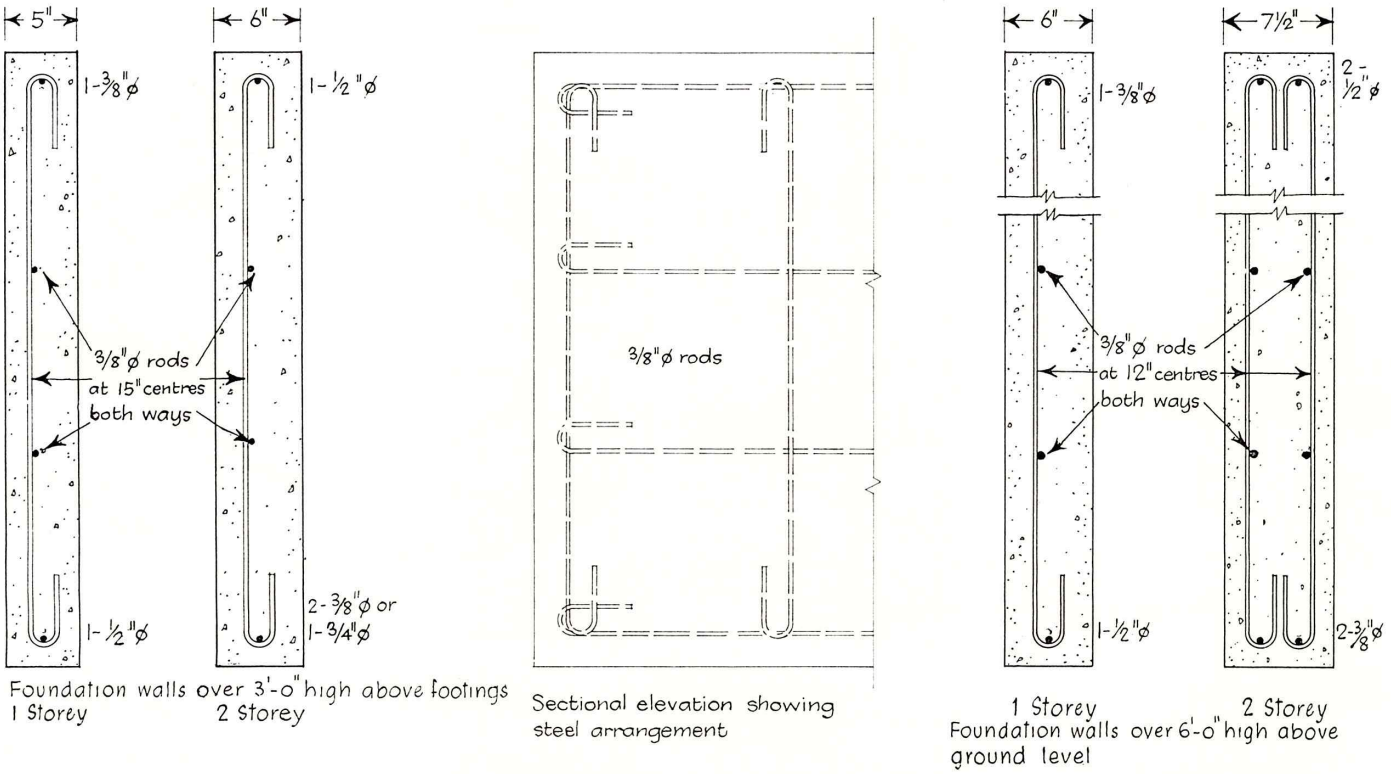


Fig. 112 *Typical arrangement of reinforcing steel for continuous concrete foundation walls above 3 ft. in height.*

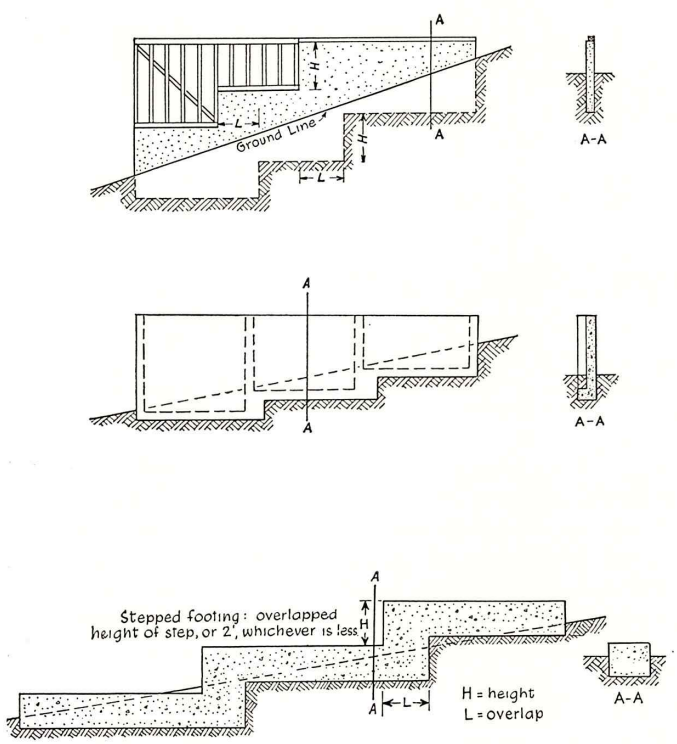


Fig. 113

Stepped foundation walls and footings

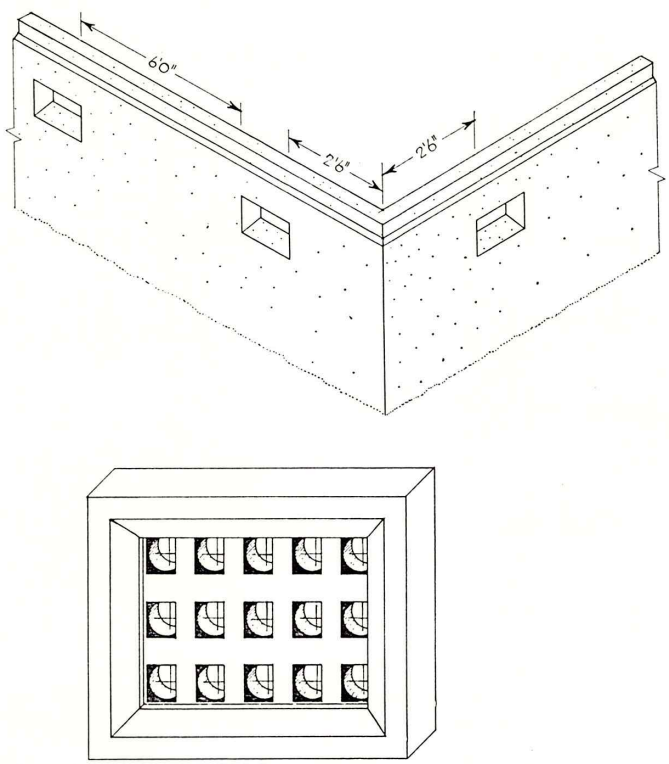


Fig. 114

Position of ventilation openings in a concrete foundation wall and typical precast ventilator

Continuous concrete foundations for wall veneer (*Fig.* 115)

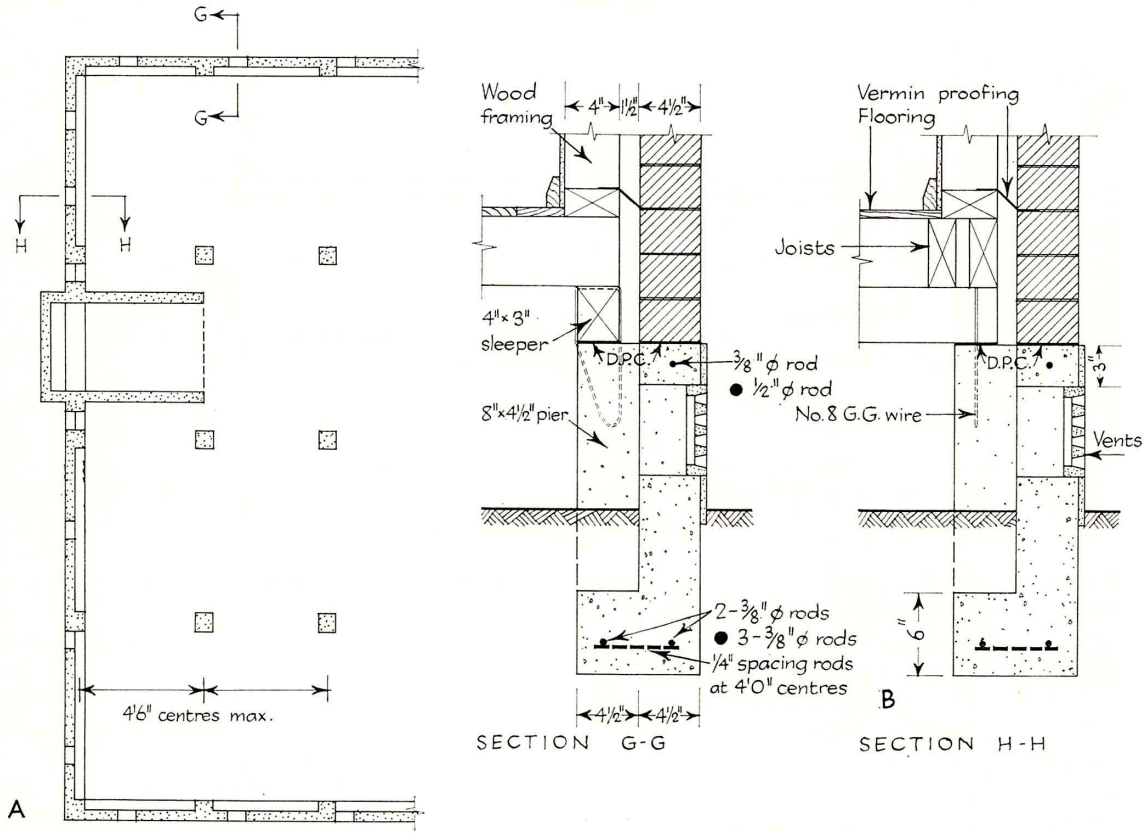
The foundations for wall veneer must be continuous walls of reinforced concrete. The footings to these walls are spread footings.

(4) ***Concrete foundations and floors for dwellings*** (*Fig.* 116)

Modern trends in construction have favoured concrete floors consisting of a reinforced-concrete slab over a layer of hardfill on the ground. The surface of the slab is sometimes finished with cork or rubber tiles and sometimes with an underlay of cork or wallboard covered with linoleum or carpet.

The advantages of such floors are:

(1) Reduced cost.
(2) There is no deterioration.
(3) Termite proof.
(4) Vermin proof.
(5) Fire resistant.
(6) Draughtproof.



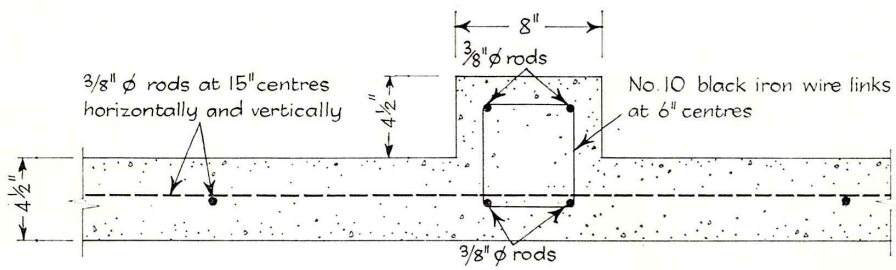


Fig. 115 *Foundation walls for brick veneer*

(A) *Part of foundation plan brick-veneer building*
(B) *Cross sections through brick-veneer foundation wall (reinforcing steel for two-storey construction indicated by large dots)*
(C) *Design of reinforcing steel in foundation walls above 3 ft. in height.*

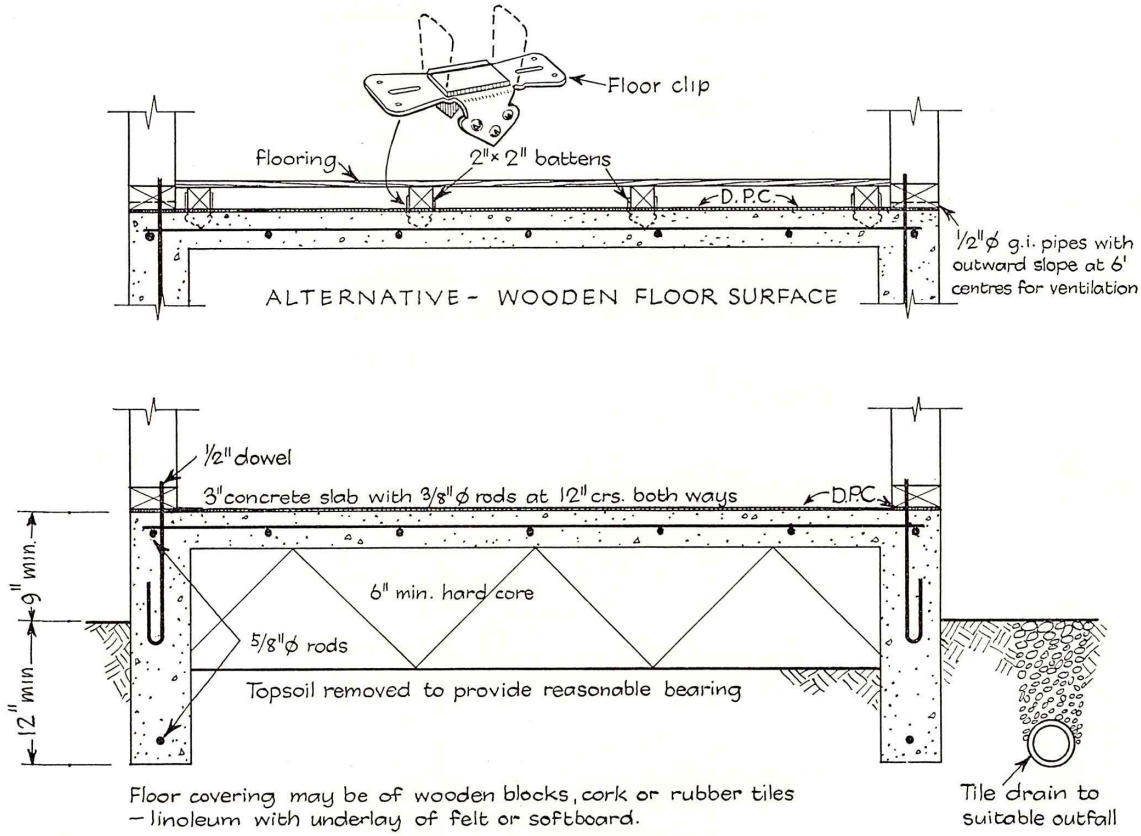

Floor clip
Flooring
2" × 2" battens
D.P.C.
½"ø g.i. pipes with outward slope at 6' centres for ventilation
ALTERNATIVE - WOODEN FLOOR SURFACE
½" dowel
3" concrete slab with 3/8"ø rods at 12" crs. both ways
D.P.C.
9" min.
12" min.
6" min. hard core
5/8"ø rods
Topsoil removed to provide reasonable bearing
Floor covering may be of wooden blocks, cork or rubber tiles - linoleum with underlay of felt or softboard.
Tile drain to suitable outfall

Fig. 116 *Concrete foundations and floor*

The site for such a dwelling must be preferably level and dry; otherwise a system of tile or scoria-filled drains must be arranged with a suitable outfall.

Typical construction includes a low foundation wall of reinforced concrete which also retains the hardfill. The height of this wall will be fixed by:

(1) Fall of the ground.

(2) Depth of hardfill.

The actual dimensions of the wall will be determined by the weight and thickness of the exterior walls.

The hardfill should be well compacted and about 6 in. in depth.

A damp-proof course is essential and may be placed below the concrete slab, in the slab, or on top of the slab. Placing the damp-proof course on the top of the slab has the advantage that it can be inspected for repairs or inspection. A damp-proof course for this purpose includes:

(1) Bitumen or asphalt roofing felt well lapped and sealed with hot bitumen.

(2) Bitumen or coal-tar pitch applied hot.

(3) Bitumen emulsions.

Foundations on ground with poor carrying capacity (*Fig.* 117)

When the local authority engineer is of the opinion that the ground on the site of the building will not support 1 ton per square foot the following requirements must be carried out:

(1) Foundations must be continuous reinforced-concrete walls.

(2) Reinforcing must be of $\frac{1}{2}$ in. bars for buildings up to two storeys and of $\frac{3}{4}$ in. reinforcing bars when buildings are over two storeys in height.

(3) Buildings of two or more storeys must have opposite external walls tied together, at intervals of 16 ft., by 6 in. concrete walls, the reinforcing rods being hooked over the rods in the outer walls. See N.Z.S.S. 1900, Chapter 6.1, for further details.

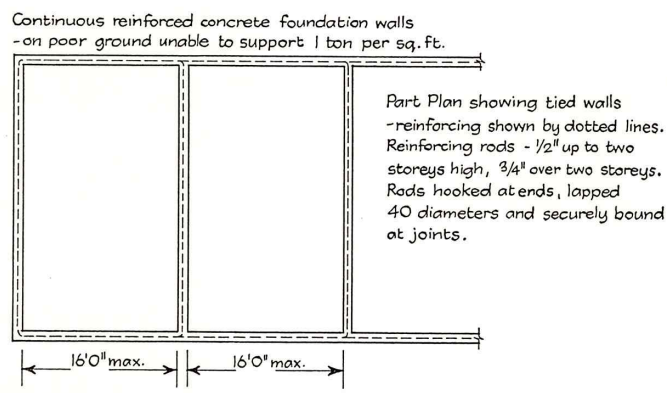

Continuous reinforced concrete foundation walls - on poor ground unable to support 1 ton per sq. ft.
Part Plan showing tied walls - reinforcing shown by dotted lines. Reinforcing rods - ½" up to two storeys high, ¾" over two storeys. Rods hooked at ends, lapped 40 diameters and securely bound at joints.
16'0" max.
16'0" max.

Fig. 117 *Plan of foundation walls on poor ground*

Questions on Chapter 4

(1) A builder makes a survey of a building site in connection with the erection of a building. What information should this survey provide?

(2) Explain briefly how you would locate with a steel tape and lines the position of the four corner pegs for a rectangular building.

(3) Describe the method and purpose of erecting profiles for the concrete foundation walls of a house. Show how each profile should be marked.

(4) How would you deal with "soft spots" found during the excavation for a foundation wall of a house?

(5) Sketch a builder's level and describe its uses for squaring the corners of a building.

(6) When the shape of a building has been set out it is necessary to take levels at various points. Explain how the levelling is carried out and also how you would ensure that the datum given by the architect remains constant throughout the job.

(7) At what spacings are piles arranged in rows and between rows in the foundation of a house?

(8) The floor of a house is to be 2 ft. 3 in. above ground at the rear and 7 ft. 6 in. at the front. What internal foundation structure would you suggest when the outside walls are of reinforced concrete. (Exclude bearing walls.)

(9) The outside walls of a house are of concrete 5 in. thick and 2 ft. 9 in. high. Sketch a cross section of the wall and show the position of the reinforcing steel.

(10) How would you ensure that the reinforcing steel is not displaced during concreting? What concrete cover would you allow between reinforcing and the face of the concrete in:
(a) walls.
(b) floors?

(11) What are the advantages to be gained by building a house with a concrete floor? Are there any disadvantages with such a floor?

(12) If a house is to be built with a reinforced-concrete floor how and where would the floor be proofed against dampness, and what materials would be used?

(13) (a) Sketch a survey peg with the usual markings on the peg.
(b) What precautions should a builder take before he commences building operations on a particular section?
(c) What would you do if the survey pegs on a building site could not be located?

Calculations

(1) A rectangular building has a foundation trench measuring 45½ ft. by 27½ ft. on the outside edges. The trench has an average depth of 1 ft. 3 in. and is 11 in. wide. Find the number of cubic feet of earth to be excavated.

(2) A rectangular block of concrete contains 1,404 cu. ft. What is its thickness if the area of its upper surface is 108 sq. ft.?

(3) What is the cost of placing 68½ cu. yd. of concrete in the foundations of a building at a cost of £7 3s. 9d. per cu. yd.

(4) An excavation is to be made on a uniformly sloping site for the basement of a building which is 42 ft. long and 37 ft. 9 in. wide. The excavation is to be commenced at the front building line and continued horizontally to the rear of the building where the depth of the excavation will be 7 ft. Calculate the number of cubic yards of earth to be removed.

(5) Concrete for a foundation wall may be assumed to weigh 144 lb. per cubic foot. Find the weight of a concrete block 4 ft. 8 in. square and 1 ft. 4 in. thick.

Chapter 5

FLOOR FRAMING

Ground-floor supports

Ground-floor supports are all parts of a frame above the foundations which directly or indirectly support the ground floor, and consist of sleeper plates, stringers, wall plates, wooden dwarf walls, and joists as follows:

Sleeper plates (or sleepers)

Sleeper plates for the average house are usually of 4 in. x 3 in. timbers laid on edge on the top of piles and spaced according to the particular span of floor joists used. (See Table 7, N.Z.S.S. 1900, Chapter 6.1.) If, for instance, 5 in. x 2 in. floor joists are specified the sleeper plates are placed in rows not more than 7 ft. apart, but with 7 in. x 2 in. joists they may be up to 10 ft. 6 in. apart. When the span of joists is up to 9 ft. 0 in., 4 in. x 3 in. timbers may be used for the sleeper plates, but heavier timbers are required for joists spanning a greater distance. (See Table 4 N.Z.S.S. 1900, Chapter 6.1.)

Timber quality

Bylaws provide that sleeper plates must be either heart quality or treated with a wood preservative to the approval of the Timber Preservation Authority (see Table 9 N.Z.S.S. 1900, Chapter 6.1.)

Minimum height above ground

There must be a clear distance of at least 12 in. between the bottom edges of sleeper plates and the ground. The object of this provision is to ensure that the timbers cannot be affected by dampness from a ground source and also to provide access for maintenance.

Joints (*Fig.* 118)

Joints are made by either longitudinal halving or splay joints over solid support, i.e., over the centre of a pile.

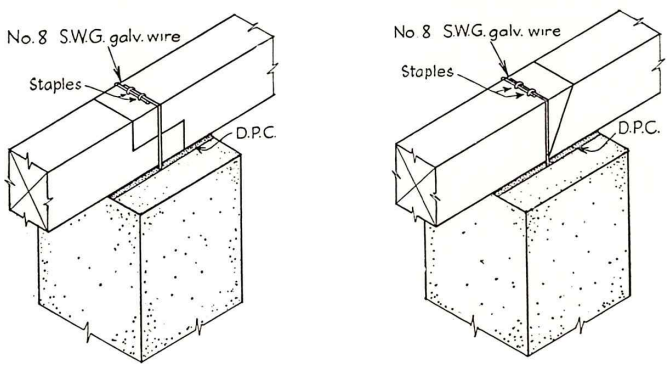


Fig. 118

Joints of sleeper plates

End bearing (Fig. 119)

The ends of sleeper plates at exterior walls should have at least 3 in. of bearing on concrete walls, piles, half piles, or wall offsets. Three different methods are shown in *Fig.* 119.

Method of securing (*Fig.* 118)

Sleeper plates are usually secured to concrete piles by two strands of No. 8 SWG galvanised wire (looped and embedded at least 6 in. in the concrete of the pile) of sufficient length to be folded over the plate for stapling. Sometimes mild-steel dowels or bolts are used for securing purposes.

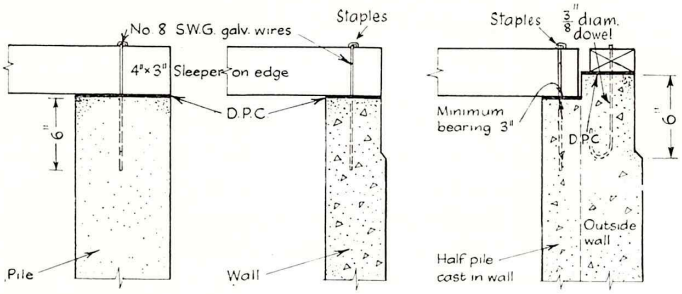


Fig. 119

End bearing of sleeper plates

Stringers

Stringers serve the same purpose as sleeper plates but are fixed on edge to the sides of piles, piers, blocks, and walls (*Fig.* 120). A stringer is usually of 5 in. x 2 in. timber but, when attached to outside walls and supporting only floor joists, it may be of 4 in. x 2 in. timber.

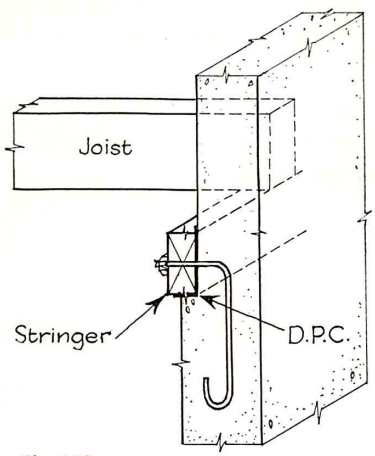


Fig. 120

Securing stringers

Wall plates *(Fig.* 121)

A wall plate is a horizontal timber used as a bearing or support for some portion of the framework of a building and is laid on a continuous wall of concrete, brick, or stone.

Timber quality

The same quality of timber is required for wall plates as for sleeper plates.

Joints

Wall plates are usually lengthened by butt joints, but sometimes longitudinal halved joints are used. Angle halvings are made at corners.

Method of securing

Wall plates are secured by $\frac{3}{8}$ in. bolts bedded at least 3 in. into the concrete wall or by $\frac{3}{8}$ in. diameter steel dowels hooked at the ends and bedded at least 6 ins. into the wall. Such dowels project at least 3 in. above the plate and have their ends clinched over and stapled. It is usual to recess the ends flush with the top of the plate. (*Fig.* 121.) Alternately No. 8 SWG galvanised wire may be used in the same manner as with sleeper plates.

Fixings are spaced at intervals of not more than 4 ft. 6 in. with fixings not more than 15 in. from ends.

Wooden dwarf walls

When the ground-floor joists are more than 4 ft. 6 in. above the ground, dwarf walls constructed of plates, studs, and braces are necessary. Such walls are of 4 in. x 3 in. timbers of the same quality as for sleeper plates.

Floor joists

Floor joists are the regularly spaced horizontal framing timbers of floors.

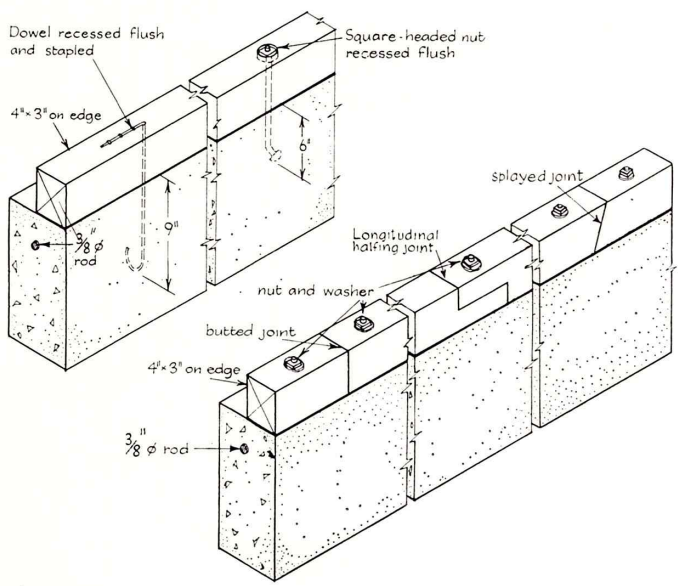


Fig. 121

Joints and fixings of wall plates

Spacing

Floor joists must not be spaced at a greater distance than 18 in. centres when flooring of a normal thickness is used.

Span

N.Z.S.S. 1900, Chapter 6.1 Table 7, sets out the maximum span for various sizes of floor joists.

Method of calculating joist sizes

Below is described an approximate method that may be used to determine the size of joists for dwelling-house floors. The depth of the joist (in inches) is equal to half the span (in feet) plus 2. This may be written as a formula as follows:

Depth of joist in inches $= \frac{1}{2}$ S $+ 2$, where S = span in feet.

Example

What depth of joist will be required to bridge a span of 12 ft.?

Depth of joist $= \frac{1}{2}$ S $+ 2$

$= (12 \div 2) + 2$

$= 6 + 2$

$= 8$ in.

This calculation is made for 2 in. joists.

Carrying strength of joists

The carrying strength of a joist is proportional to

$$\frac{D^2 \times T}{L}$$

where D is the depth in inches, T the thickness in inches, and L the length in feet.

(*Note: Carpenters usually speak of the width and thickness of a joist but when in position the width of a joist is known as its depth.*)

A piece of 4 in. x 3 in. contains the same amount of timber, for each foot of its length, as a piece of 6 in. x 2 in., but would it have the same carrying capacity?

Example

Compare the proportional carrying strength of a 4 in. x 3 in. with that of a 6 in. x 2 in. joist for a span of 6 ft. Using the above formula the results are as follows:

4 in. x 3 in. joist: $\frac{4^2 \times 3}{6} = \frac{4 \times 4 \times 3}{6} = 8$

6 in. x 2 in. joist: $\frac{6^2 \times 2}{6} = \frac{6 \times 6 \times 2}{6} = 12$

The 6 in. x 2 in. will carry the greater weight in the ratio of 12 to 8 or 3 to 2.

Floors in dwellings are made strong enough to carry about 40 lb. per square foot of floor surface, while the floors of warehouses, etc., subject to heavy loads, are capable of bearing loads of 60 lb. per square foot and upwards.

Lengthening of joists (*Fig.* 122)
Floor joists are joined together over the sleeper plates by overlapping at least 12 in. on every third pair of joists, or by butting as shown.

Joists under bearing partitions (*Fig.* 123A)
As a bearing partition supports the roof or other portions of the structure, double joists, separated by packing pieces 24 in. apart, must be placed under bearing partitions. A non-bearing partition (*Fig.* 123B) is one that does not support any load other than its own weight.

Trimmers (*Fig.* 124)
A trimmer is a framing timber fixed between joists, studs, rafters, etc., carrying the ends of such timbers that have been cut to provide an opening for a stair, door, window, etc. A "trimmer joist" is a joist which supports the end of a trimmer.

Damp-proof course (*D.P.C.*)
A damp-proof course is a durable waterproof material placed between brick, stone, or concrete and timber to protect the latter from moisture.

Origin of dampness
Walls of concrete and brickwork are liable to become damp in three ways:
(1) By dampness rising up a wall from the ground.
(2) By dampness passing through from the exposed faces of walls.
(3) By dampness passing down from the tops of walls.

The carpenter is mainly concerned with the protection of timber in contact with brick or concrete walls and this protection is effected by placing a damp-proof course, usually a layer of bituminous fabric, between the timber and the brick or concrete, e.g., under plates

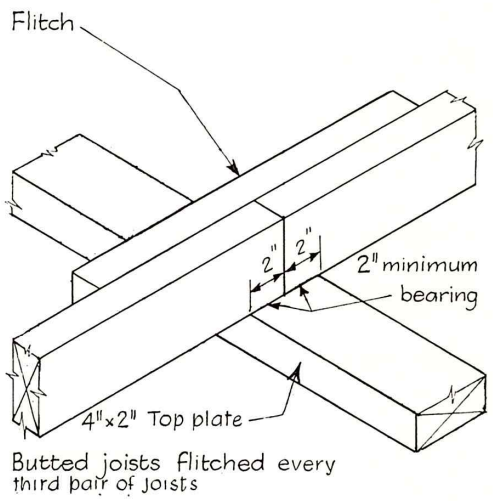


Fig. 122
Two methods of lengthening floor joists

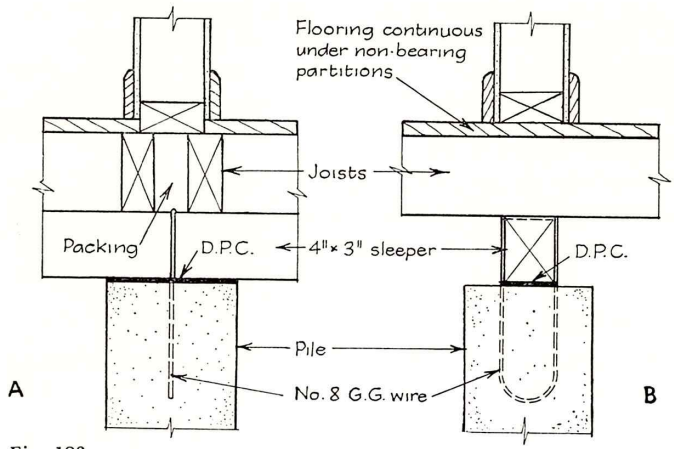


Fig. 123
Bearing and non-bearing partitions
(A) *Joists under bearing partition*
(B) *Non-bearing or swinging partition*

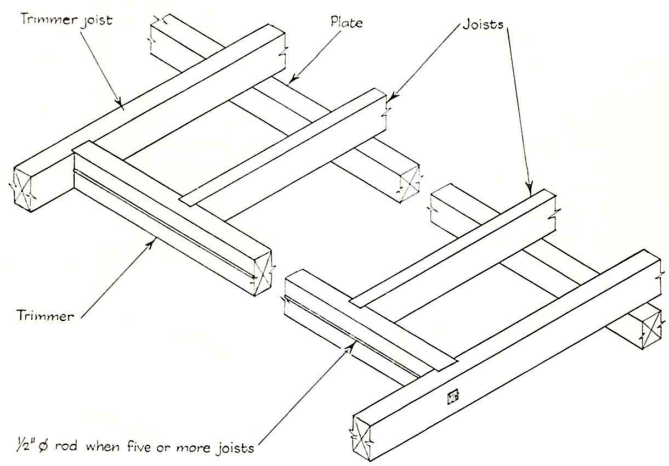


Fig. 124
Arrangement of trimmer joists

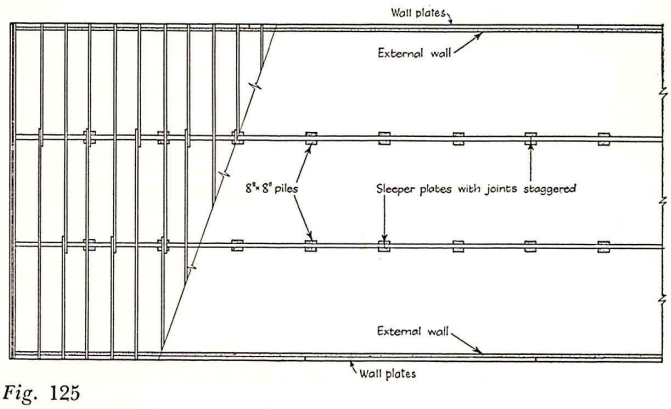
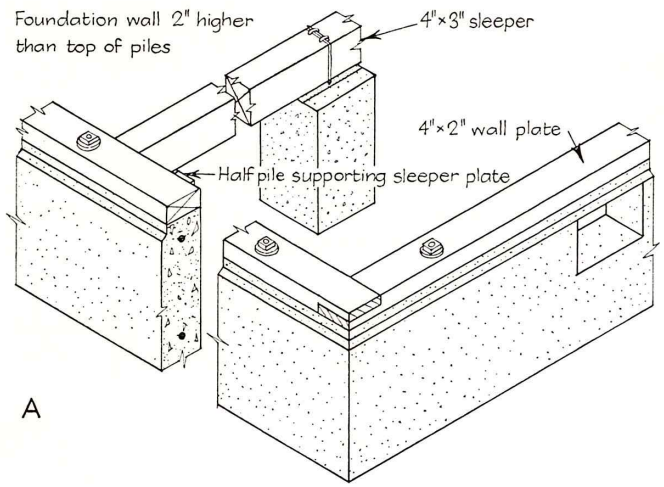


Fig. 125

Foundation plan showing piles, sleepers, wall plates, and joists



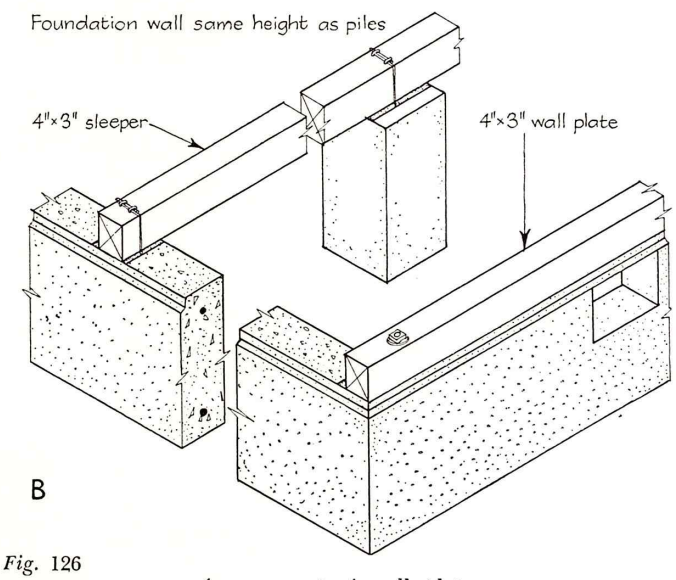


Fig. 126

Arrangement of wall plates

(A) *Continuous 4 in. x 2 in. wall plate*

(B) *4 in. x 3 in. wall plate*

which would otherwise be in contact with concrete. The ends of timbers must be kept away, say $\frac{1}{2}$ in., from concrete surfaces and given protection by a coating of some preservative substance such as tar. Tar and sand are at times used as a damp-proof course.

Construction work

When the concrete foundation walls and piles have been completed the next job is to lay the wall plates, sleeper plates, and then the floor joists (*Fig.* 125).

Arrangement of wall plates

The particular procedure of laying wall plates may differ in one district from that used in another but two typical methods are as follows:

(1) A 4 in. x 2 in. continuous wall plate is laid on top of the foundation walls (*Fig.* 126A).

(2) A 4 in. x 3 in. wall plate on its edge is laid on opposite foundation walls (*Fig.* 126B).

Laying of wall plates

Where the plates will rest, lay a suitable damp-proof course of, say three-ply bituminous felt, and then cut wall plates to length.

Set up a building line (*Fig.* 127) corresponding to the outside of the plate and from it measure to the centre of each holding-down bolt or dowel; square across from bolt positions to the plates and bore holes for the bolts. Square holes are often made in the tops of plates so that nuts of bolts can be recessed flush. (Grooves are made for the ends of dowels to be recessed when these are used.)

Lay the plates in position and tighten nuts on bolts. If the top of the concrete wall has been accurately finished the wall plates should seat level and straight on the wall, but it is advisable at this stage to make a

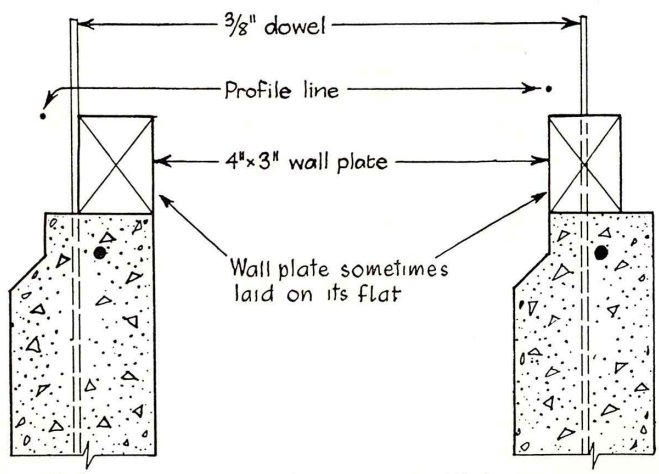


Fig. 127

Marking positions of dowels (or holding-down bolts)

check; so with a level set up about the centre of the job, check to several points about the outside wall and sight or use a straight edge for checking on intermediate points along the wall.

Laying of sleeper plates

(1) Arrange to have the "round edge" of sleepers uppermost; arrange joints centrally over piles; splay or half-lap the joints and then cut to the various lengths required. For the half-lap joints in the sleepers, gauge from the bottom of the sleeper so that any discrepancies in depth are uppermost and are automatically corrected when measuring for the depth of the joists.

(2) Secure sleepers at the ends (not omitting damp-proof course) and check for straightness on the sides and top edges; then secure to piles.

Methods of setting out joist positions *(Fig.* 128)

In most specifications the spacing of the various framing members is stated as "centre to centre" measurements, but in actual practice the carpenter finds it easier to use the "in and over" method. The distance is the same whichever method is used.

Note: When the blade of the try square is 2 in. wide, both sides of a joist position can be marked without moving the square.

Example of setting out joists

Room length, 12 ft.
Joist spacing 18 in. "in and over".
No. of spaces between joists = 8.
No. of joists = 9.

Note: There is always one more joist than there are spaces.

To find the spacing between joists

Nine 2 in. joists take up a distance of 18 in. leaving a distance of 10 ft. 6 in. to be divided into 8 spaces. This equals $15\frac{3}{4}$ in. between joists. 2 in. (the thickness of a joist) added to $15\frac{3}{4}$ in. gives $17\frac{3}{4}$ in. "in and over" measurement.

To set out the joist positions on a plate, mark the first joist (2 in.) and then use the "in and over" measurement to the end of the plate. (*Fig.* 128.)

Alternative method. Take the thickness of the first joist from the overall length of the room and divide this distance by the number of spaces. This gives "centre to centre" or "in and over" measurement.

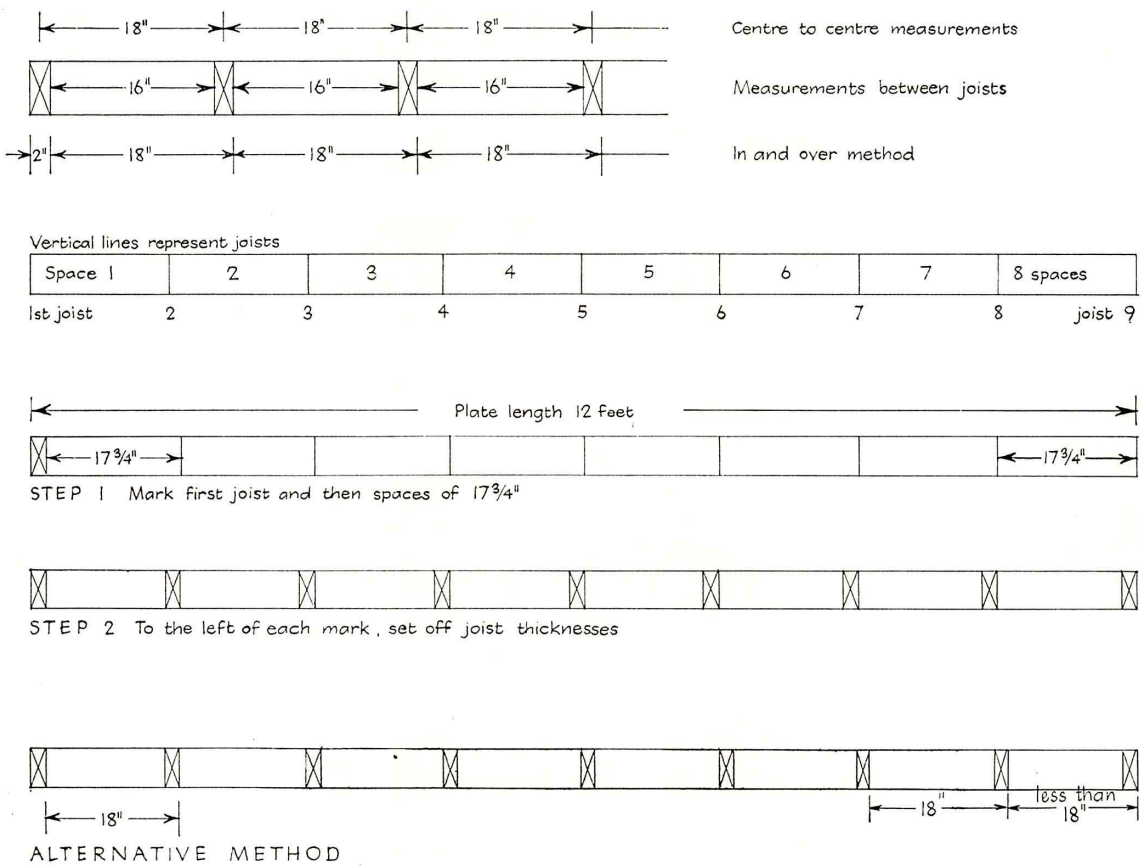


Fig. 128

Methods of setting out joist positions

Another method of arranging joists is shown in *Fig.* 128 where joists are spaced at the standard distance of 18 in. centres to near the end of the building, and the last one or two spaces are made less than the standard distance. This is quite a common method.

Arrangement of joists (*Fig.* 129)

(1) Set out positions of outside joists, which may be double joists with packing between (*Fig.* 129A) or a single joist with "soldiers" attached (*Fig.* 129B).

(2) Locate positions of the bearing partitions from the plan; measurements on plan are framing sizes usually indicated clearly, so that with a room 12 ft. wide there would be 12 ft. between plates or studs. Remember that the double joists under bearing partitions are spaced widely enough to provide support for the ends of flooring (*Fig.* 123).

(3) Divide the distances between sets of double joists, or the double joists and outside joists into 18 in. centres, by methods already explained.

Note: Clearly mark joist positions.

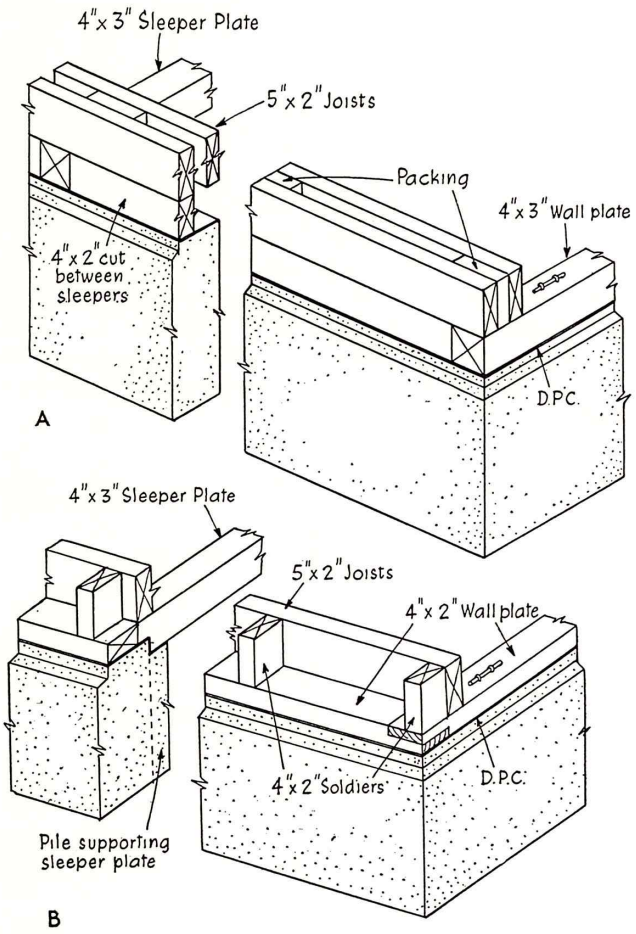


Fig. 129

Arrangement of joists

(A) *Double joists*

(B) *Use of soldiers*

Depth of joists

As rough-sawn joists vary in width and as variations in the height of piles or thickness of sleeper plates can occur, joists must be gauged and checked over the wall and sleeper plates so that when the joists are fixed all their top edges will be in line. A 5 in. x 2 in. joist would be gauged and checked at about $4\frac{3}{4}$ in. or $4\frac{7}{8}$ in. The checking of joists is avoided if they are thicknessed (run to a standard width), provided, of course, that the tops of the sleeper and wall plates are dead in line.

Measuring depths of joists (*Fig.* 130)

The most common method used to determine the depths of joists is to stretch a line (over each sleeper plate) from the end joists which have already been fixed and then to measure, at each joist position, the depth of each joist from the sleeper plate to the line. When a sleeper plate is unduly low, instead of placing packing pieces under the joists, it is preferable to raise the sleeper to suit with packings of cement mortar on the piles.

The actual procedure is: (1) Gauge and check the double joists at the ends of the building to a depth of say $4\frac{7}{8}$ in. above sleeper plates. (2) Across each sleeper plate a line connecting end joists is stretched tightly, and over a long distance the sag must be taken out of the line. To prevent these lines being in the way of joists as they are placed they are packed up 1 in. above the top of the joists. (3) At each joist position the distance is measured from the line to the top of the sleeper. This distance reduced by 1 in. is the depth of the particular joist, which can be gauged and checked.

It is usual over long spans to set up the centre line of joists and then intermediate joists in that order.

An alternative method, convenient for small jobs, is that of using a long straight edge instead of a line as described.

Note: The rounded edges of all joists are placed one way for checking and are kept upwards when the joists are nailed in position.

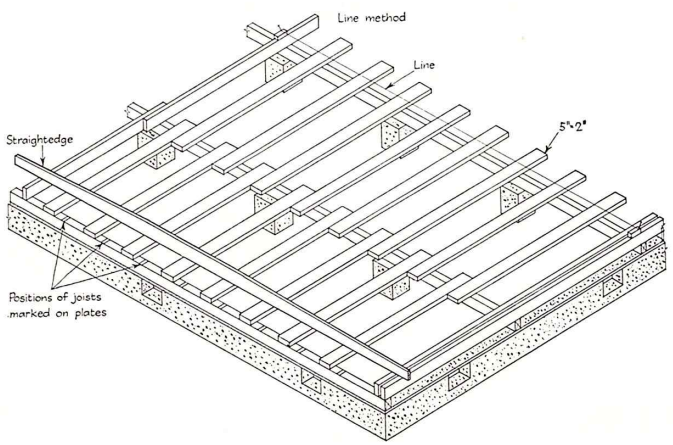


Fig. 130

Measuring depths of joists (line and straightedge methods shown)

Nailing (*Fig.* 131)

Joists are skew nailed to the sleepers with either 3 in. or 4 in. nails at an angle of 45° from either side, and nailed together, where overlapped, with 4 in. nails. Heart rimu joists could conveniently be nailed with 3 in. nails, but radiata pine joists would require nailing with 4 in. nails, preferably with flat heads. Immediately before nailing, joists should be straightened sideways and held while the nails are being driven into the sleeper plates.

Fig. 131

Nailing of joists

Framings of openings in floors

Trimming is the process of framing timbers about stair wells, chimneys, or any other openings in the floor which interrupt the continuity of the joists. The ends of joists cut to form the opening are framed into a trimmer which in turn is framed into trimmer joists (*Fig.* 124). As all joists are of the same depth, the trimmer and trimmer joists must have an increased breadth of 1 in. over ordinary floor joists to enable them to support the extra load. One joint used at the junction of the timbers is shown in *Fig.* 132A. A trimmer supporting five or more joists is strengthened by angle cleats (*Fig.* 132B) or a steel rod as shown in *Fig.* 124.

Notching of joists

The New Zealand Standard Specification 1900, Chapter 6.1, states that beams, joists, or girders shall not be notched on their edges at any point more than 18 in. from a support and they shall not be bored for any purpose at a point other than on the neutral axis (*Fig.* 133) except at a lessor distance from a support than three times their depth. Such notches or holes shall not exceed in size one-fifth of the depth of the joist or beam or $1\frac{1}{4}$ in., whichever is the less. Where the joists are of greater depth than are structurally required by their immediate situation no objection shall be taken to notches which do not reduce them to below the minimum.

Note: The position of the neutral axis is shown in Fig. 133 in a simple beam supported at each end and subject to a load; the top portion of the beam will be in compression and the bottom portion will be in tension. If the top portion of a beam is being crushed or shortened by compression and the bottom portion is being stretched by tension there must be some line or point at which the stress changes and at this line there cannot be any stress. This line, not being subject to compression or tension is neutral and is known as the neutral axis.

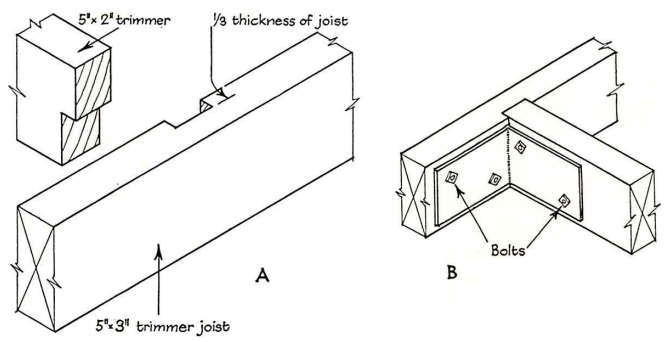


Fig. 132

Trimmer joint

(A) *One kind of trimmer joint*
(B) *Trimmer joint strengthened with angle cleat*

Upper floor joists

The joists of upper floors are supported by the external walls and partitions and are placed across the shortest span of the space to be bridged. The two methods used are shown in *Fig.* 134.

Bearing of joists

Wherever possible joists should be run continuously over partitions or be jointed by overlapping as for other joists. However, where sufficient bearing is available, such as on a top plate of a partition, the joists can be butted centrally and strengthened by a flitch nailed to the sides of every third pair of joists, (*Fig.* 122.) At external walls the joists can be supported by a wall plate, as in platform construction, or a 4 in. x 1 in. ribbon board—a horizontal framing timber checked into the studding—and bolted or well spiked into the studs, as in balloon frame construction.

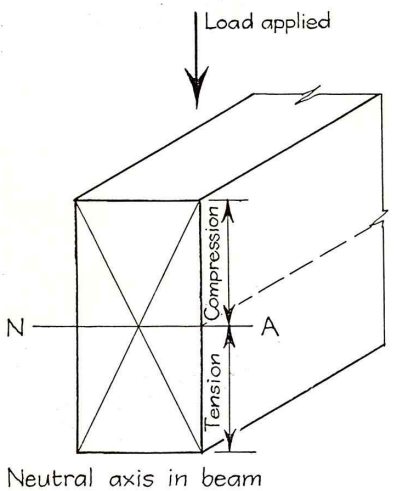


Fig. 133

Neutral axis of beam

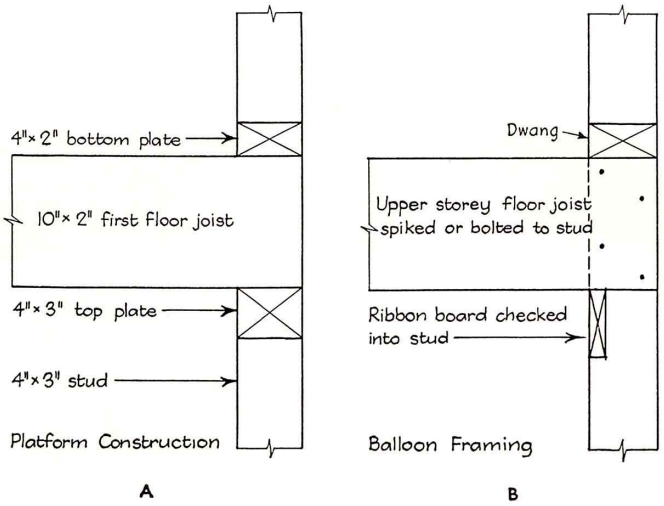


Fig. 134
Methods of fixing first-floor joists to external wall
(A) *Platform construction*
(B) *Balloon-frame construction*

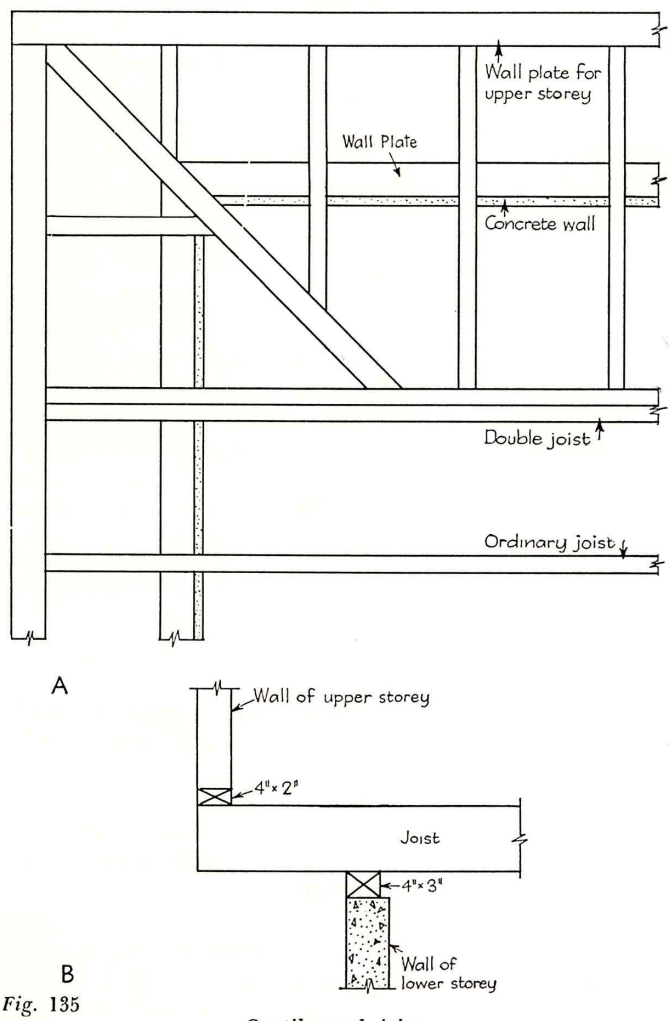


Fig. 135
Cantilevered joists
(A) *Plan of cantilevered joists*
(B) *Elevation of cantilevered joist*

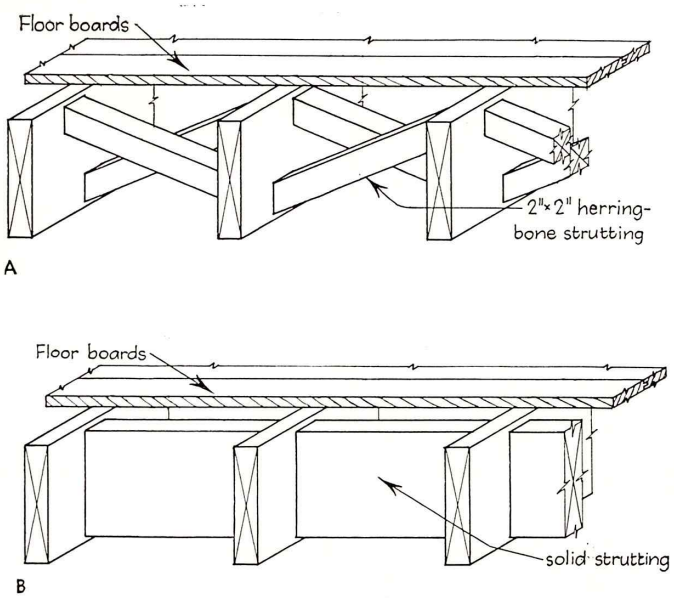


Fig. 136
Methods of stiffening joists
(A) *Herringbone strutting*
(B) *Solid strutting*

Dimensions of floor joists

The dimensions of joists depend entirely on the distance they span and the load they have to carry. The maximum span, and the live load able to be carried by the various sizes of floor joist is set out in Table 7, N.Z.S.S. 1900, Chapter 6.1.

Cantilevered joists (*Fig.* 135)

Cantilevered joists are those which project beyond the wall of the lower storey or basement.

Methods of stiffening joists

When joists carrying a live load not exceeding 60 lb./sq. ft. and spanning a distance in excess of 8 ft., they must be stiffened at 8 ft. intervals with either herringbone strutting (*Fig.* 136A) or solid strutting (*Fig.* 136B). Herringbone strutting is of 2 in. x $1\frac{1}{2}$ in. pieces of timber arranged as shown, and solid strutting of solid struts or dwangs not less than $1\frac{1}{2}$ in. thick by the full depth of the joists.

Length and bevel of herringbone struts (*Fig.* 137)

Herringbone strutting should not be fitted flush to the top or bottom edges of joists but kept $\frac{1}{4}$ in. to $\frac{1}{2}$ in. away from both edges. This allows the joists to shrink without causing the strutting to interfere with floor boards or ceiling material.

The length and bevel of the herringbone strutting is found by first stretching a line between where the struts will be fixed and another line parallel and 11 in. away. This is the depth of the strutting against a 12 in. joist. Then place a piece of strutting timber across the joists as shown and mark the underside of the piece to the line of the joists. When the joists are evenly spaced it is necessary only to mark the first strut and then, after it has been checked for fit, use it as a pattern to cut as many others as are required.

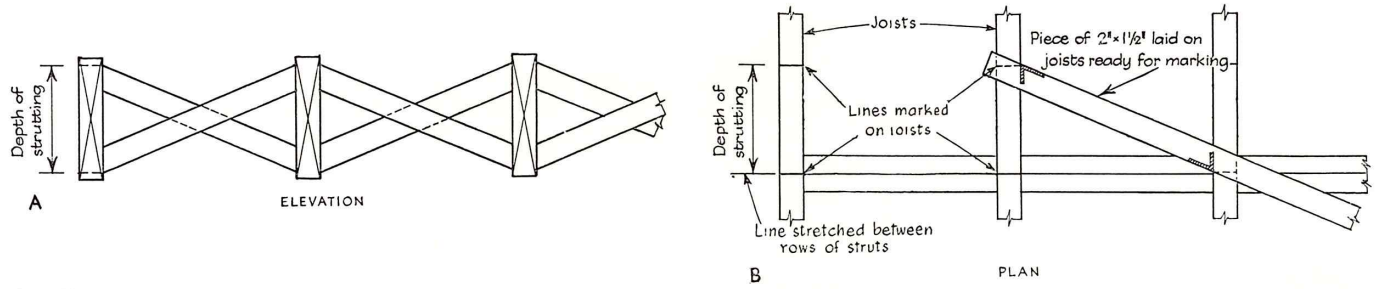


Fig. 137

Method of marking herringbone struts

(A) *Depth of strutting* (B) *Finding length and bevels of struts*

Questions on Chapter 5

(1) Describe how you would set out, arrange, and fix the floor joists to their correct height. Assume that the sleeper plates have already been fixed.

(2) (a) What arrangements are necessary when the ground-floor joists require to be set more than 4 ft. 6 in. above the ground?
(b) Would you consider 2 in. end bearing sufficient for a sleeper plate?
(c) At what distance should sleeper plates be spaced for 5 in. x 2 in. joists?

(3) State the dimensions of the bottom plates required:
(a) In bearing walls of a single-storey house.
(b) In bearing walls of a two-storey house.
(c) In non-bearing partitions.

(4) (a) Sketch two methods of joining sleeper plates.
(b) Show how a sleeper plate is secured to a pile.

(5) What quality would you recommend for the sleeper plates of a house and how far would you place them above the ground?

(6) State the dimensions of wall plates for a single-storey house with a continuous concrete foundation wall. Sketch two methods of securing the plate to the wall.

(7) Show how the joists are arranged under a partition that supports the roof. Should the joists be placed exactly under or to one side of the partition?

(8) Explain the cause of dampness in a foundation wall and methods used to protect timber bearing on the wall.

(9) Describe with sketches how the upper floor joists in a two-storey house are:
(a) Supported and secured to the wall framing.
(b) Stiffened.

(10) A square opening with side of 4 ft. 6 in. is to be trimmed in a floor for a chimney. Show how you could arrange the joists about the opening, supposing that the chimney is in the middle of a floor.

(11) Describe the "in and over" method of setting out the positions of floor joists.

Calculations

(1) A carpenter receives a basic wage of £13 for a week of 40 hours. In addition, he works $1\frac{1}{2}$ hours overtime per day at a rate of time-and-a-half and receives an allowance of 1 hour per day for travelling time at ordinary rate as well as a tool allowance of 2d. per hour. What is the total sum he would receive at the end of each week?

(2) How many joists spaced at 18 in. centres would there be in:
(a) 48 ft. of floor.
(b) 32 ft. of floor?
Note: There will be one more joist than spaces between the joists.

(3) A plank 23 ft. long, $3\frac{3}{4}$ in. thick tapers uniformly from 8 in. at one end to 5 in. at the other. Find its volume.

(4) A timber frame 12 ft. by 9 ft. requires two diagonal braces from corner to corner. How long is each brace?

(5) The strength of a joist is proportional to its width when the depth and span are equal. If a douglas fir joist 9 in. x 4 in. will carry a load of 2 tons, what load will a 9 in. x 3 in. joist of the same timber carry?

Chapter 6

WALL FRAMING

Timber-frame construction

Consideration will first be given to the several types of wall framing for single- and two-storey buildings of timber-frame construction, and then the usual methods of construction will be described.

Timber-frame construction
A building of timber-frame construction is one that is framed with studs, plates, and braces for covering with sheathing and lining of various materials.

Framing timber
Framing timber supports the structure, resists any external forces applied to the building, and provides fixing for coverings.

Grades of framing timber
Timber grades for both native and exotic timbers are described in N.Z.S.S. 1900, Chapter 6.1. Framing timbers should be reasonably dry and not of a lower grade than Building A (BA) with the exception of studs and plates of non-bearing partitions which should not be of a lower grade than Building B (BB) and No. 2 Framing.

Single-storey construction (*Fig.* 138)
In single-storey construction the studs are continuous from the bottom to the top plate.

Platform construction (*Fig.* 139)
Platform construction is a common system of framing used for buildings of timber frame construction of *more* than one storey, in which the studs are not continuous.

Balloon-frame construction (*Fig.* 140)
Balloon-frame construction is a system of construction used in buildings of more than one storey, in which the studs are continuous from the bottom plate to the top plate.

Semi-balloon construction (*Fig.* 141)
Semi-balloon construction is similar to balloon construction in that the corner and other important studs are continuous. The other studs are interrupted by plates at the various storeys.

Preparation of wall frames
Before the actual work of framing is started the following matters are considered:
(1) Dimensions of rooms – The dimensions of rooms as shown on a plan are known as framing sizes because they represent the exact distances between the wall framing.
(2) Sizes and spacing of studs – The sizes and spacing of studs are described in the specification of the job, the sizes usually correspond with those in *Table 5* of N.Z.S.S. 1900, Chapter 6.1.

The normal spacing of studs is 18 in. centres, but this may be varied up to 20 in. centres to suit sheathing or lining materials, e.g. wall boards 4 ft. wide—spacing 16 in. centres. Window and door openings also have to be considered when spacing is being planned. Methods previously described for the setting out of joist positions may be used in setting out the stud positions.

Framing procedure
Outside walls – Top and bottom plates
After the floor joists have been secured the following procedure is adopted:
(1) Long straight timbers are selected for the top and bottom plates. Angle halvings are made for corners and longitudinal halvings for lengthening joints, which are

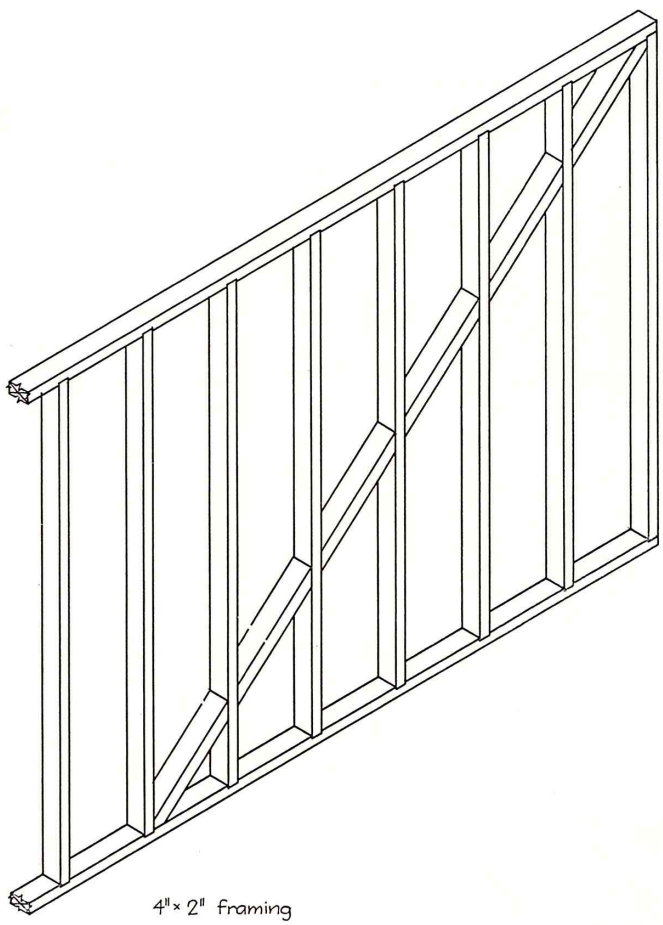


Fig. 138
Framing of single-storey building

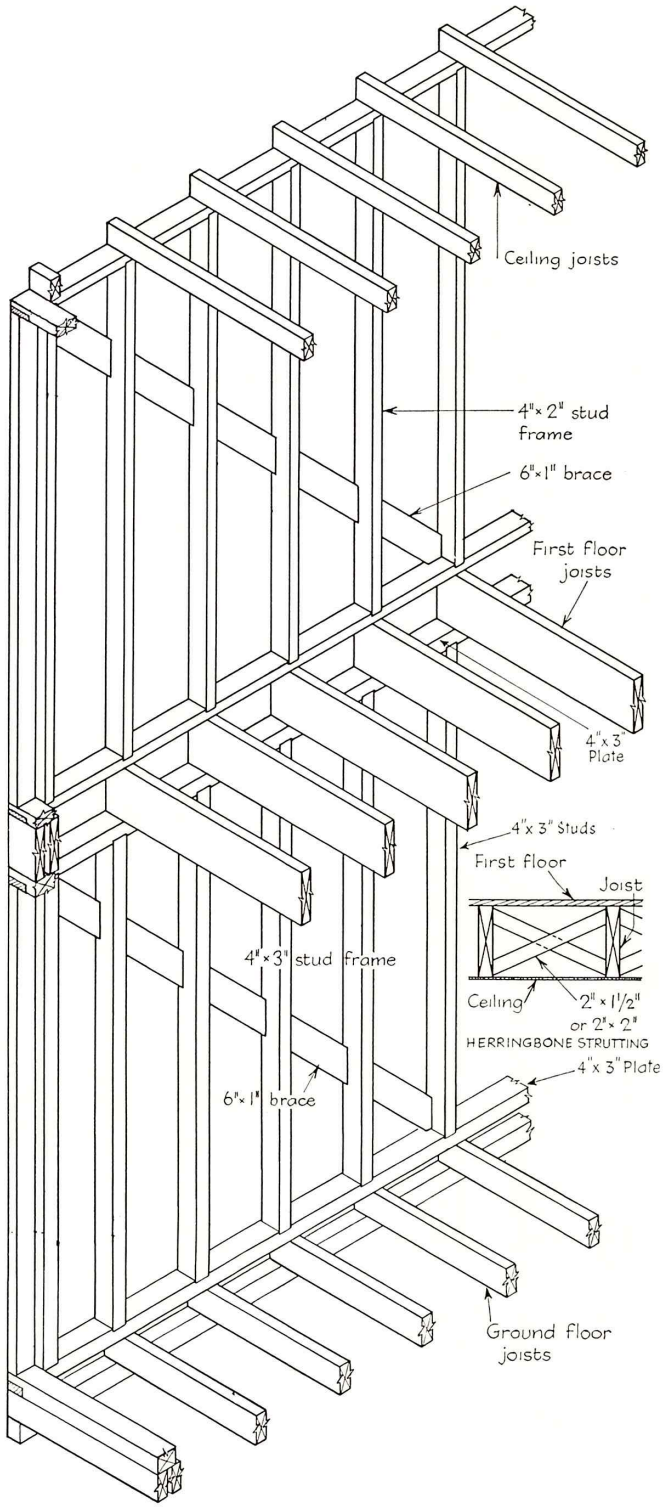


Fig. 139

Platform construction

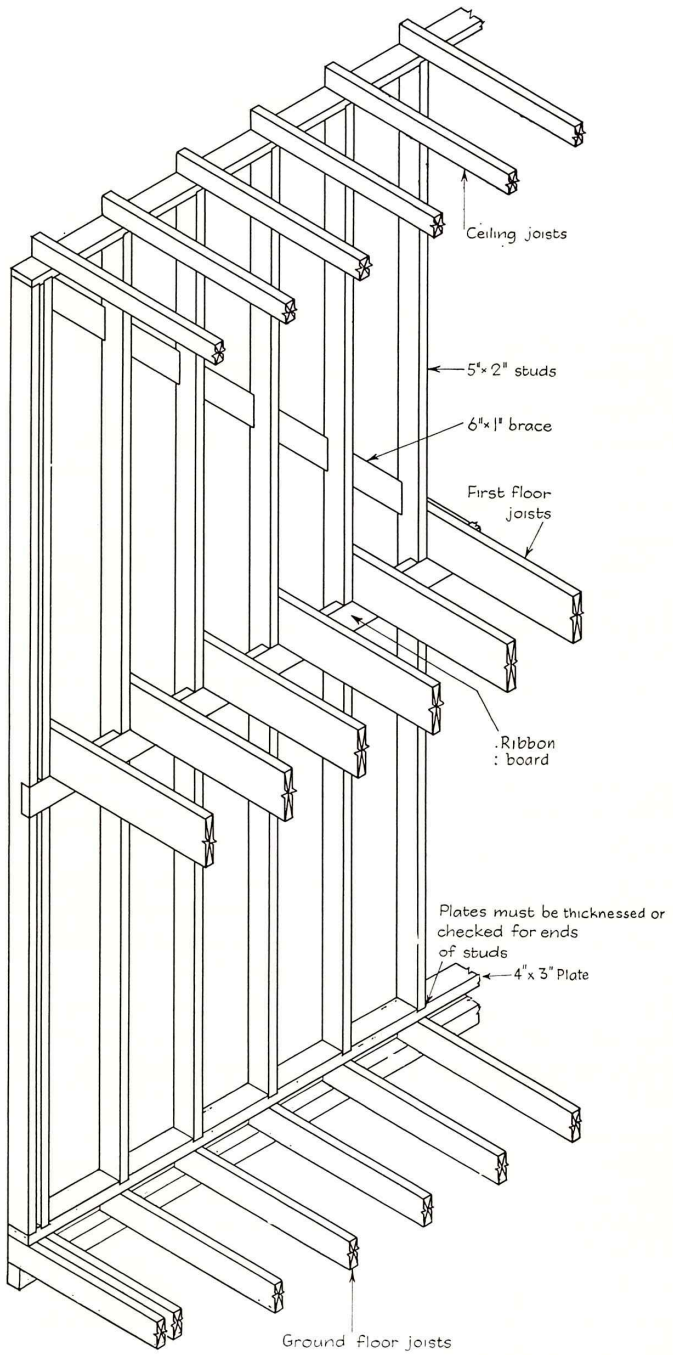


Fig. 140

Balloon-frame construction

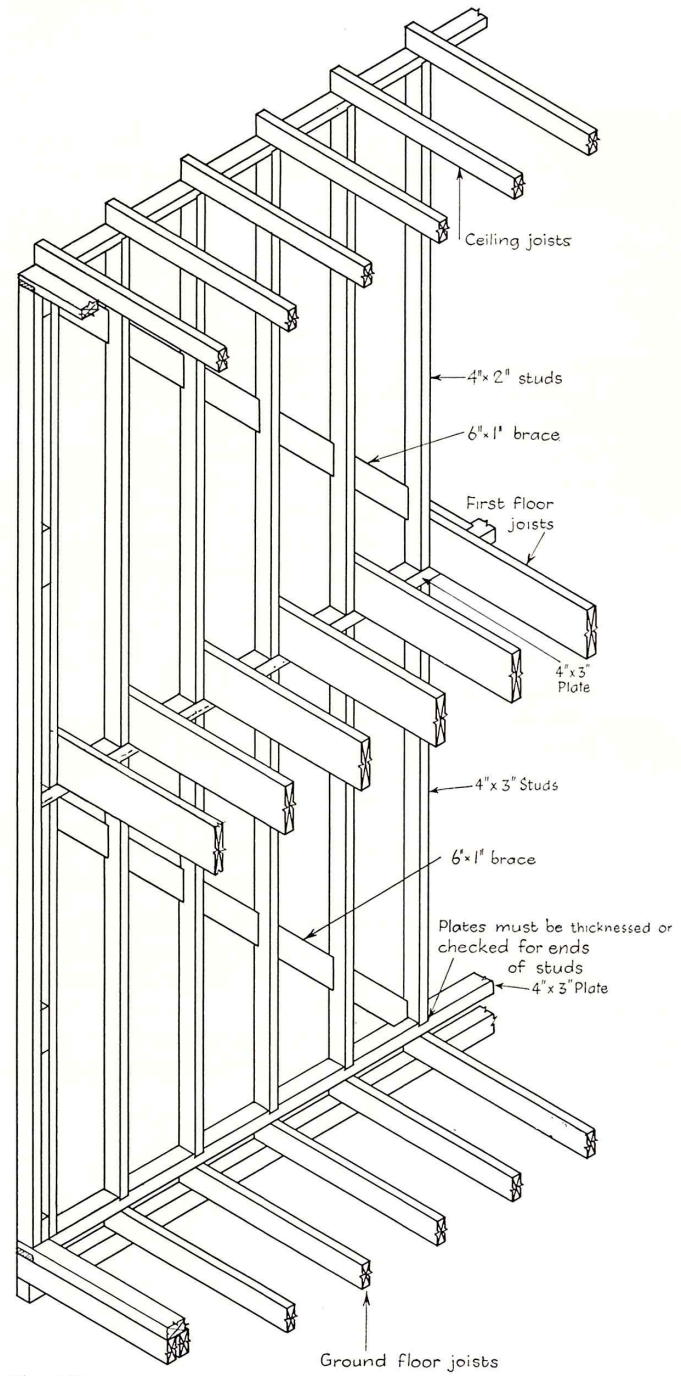


Fig. 141

Semi-balloon-frame construction

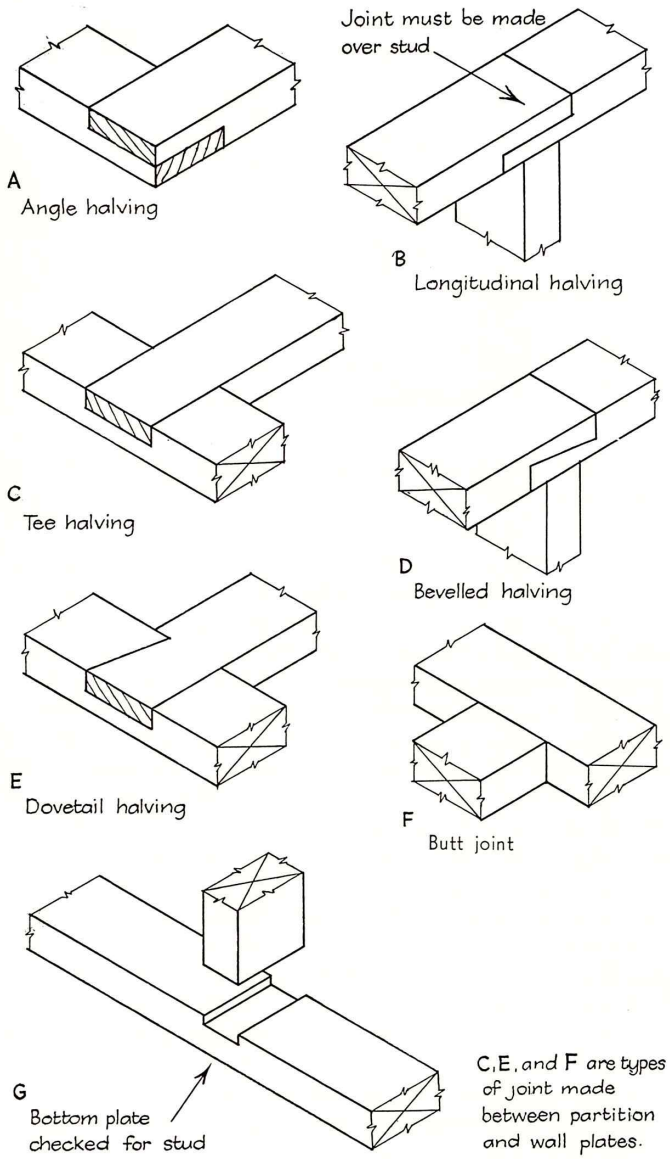


Fig. 142

Framing joints

made over such solid support as a joist or in the case of a top plate a stud. Such joints (*Fig.* 142, A, B, D), commonly known as "scarfed" joints, are gauged from the underside of the bottom plate and the top-side of the top plate.

Note: When gauging the depth of any longitudinal halving joints, gauge from the same face on both plates. It is advisable to have the various sections of plates prominently marked so that confusion cannot arise.

At the corners, the joints are arranged so that at least one corner stud may be fixed when the frame is assembled. The plates are now straightened and tacked

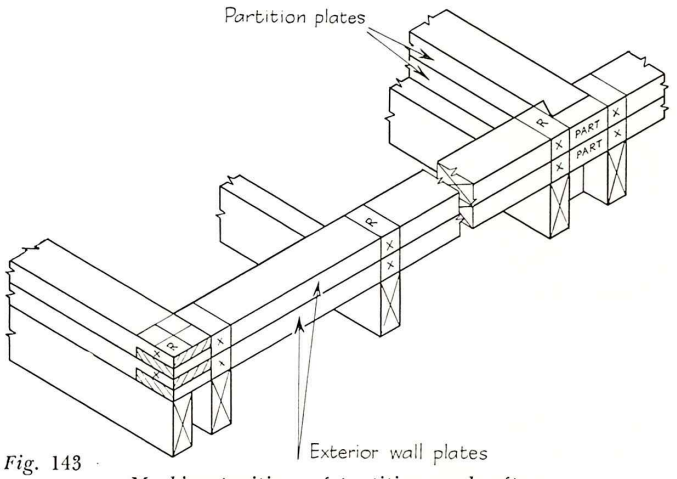


Fig. 143
Marking positions of partitions and rafters

in position with the top plate on top of the bottom plate (*Fig.* 143).

Setting out of studs

The positions of the window, door, and porch openings are set out on the outside edges of the wall plates. The joinery sizes are given in the specification, but it is advisable to have the joiner supply the exact outside dimensions of frames. A clearance of approximately $\frac{1}{2}$ in. is allowed between the sides and head of a window frame and the rough framework. Under a frame $\frac{1}{8}$ in. is allowed so that the sill trays may be slipped into place. The side and head clearances are largely dependent on the width of the architraves (usually $2\frac{1}{2}$ in.) and although $\frac{1}{2}$ in. is usually allowed for clearance this may be reduced to $\frac{1}{4}$ in. or increased to suit the circumstances. The clearance over a window frame must be sufficient to prevent the weight of the roof bearing on a window frame in the event of timbers warping or sagging.

After the openings have been marked the positions of the trimmer and other wall studs are marked on the plates.

Rafter positions are also marked on the outside plates (*Fig.* 143). The ridge also can be marked now.

Top and bottom plates for partitions

(1) The top and bottom plates for the partition walls are arranged in pairs.

(2) The ends of top plates are either stop-halved or stop-dovetail-halved into exterior plates (*Fig.* 143), but bottom plates are butted against exterior plates. Other joints are as for exterior walls.

(3) Top and bottom plates are fitted and placed together in their correct positions for marking the locations of the ordinary and trimmer studs for door openings.

Housing plates for studs

The tackings in the plates are now removed and the plates gauged for the stud housings by gauging from the top of the top plate and the bottom of the bottom plate to a depth of about $1\frac{3}{4}$ in. for a 2 in. plate.

The housing of plates prevents the studs from twisting as a result of shrinkage and also ensures that all wall frames will be of the same height when assembled. This latter advantage can be obtained also by using thicknessed plates. Plates in buildings of more than one storey must be either housed or thicknessed.

Preparation of studs

When there are four men on a job two will be engaged in setting out the plates while the other two are sawing the studs to length.

Length of studs

In most cases bylaws specify that ceilings must not be less than 8 ft. in height from floor level, which means that there should be a clear distance of 8 ft. between floor and ceiling. When standard 8 ft. wall linings are to be used the studs should be of sufficient length to allow a $\frac{1}{2}$ in. clearance for fixing the sheets.

The length of studs is found by subtracting the combined thickness of the top and bottom plate (or twice the gauged distance when plates are housed for studs) from the sum of the ceiling height, clearance for wall sheets, and floor and ceiling thicknesses. The following is a typical example:

	ft.	in.
Height from floor to ceiling	8	0
Clearance for 8 ft. wall sheets		$0\frac{1}{2}$
Ceiling thickness		$0\frac{3}{8}$
Floor thickness		$0\frac{3}{4}$
	8	$1\frac{5}{8}$

Wall plates 2 in. gauged at $1\frac{3}{4}$ in. $= 3\frac{1}{2}$ in.
Stud length $= 97\frac{5}{8} - 3\frac{1}{2} = 94\frac{1}{8}$ in. $=$ 7 ft. $10\frac{1}{8}$ in.

This is the length of studs for exterior walls and bearing partitions. The studs for non-bearing partitions are reduced in length by a distance equal to the thickness of the flooring. It is advisable to mark these measurements on a rod and, after checking thoroughly, transfer them to a pattern stud from which other studs are sawn to length.

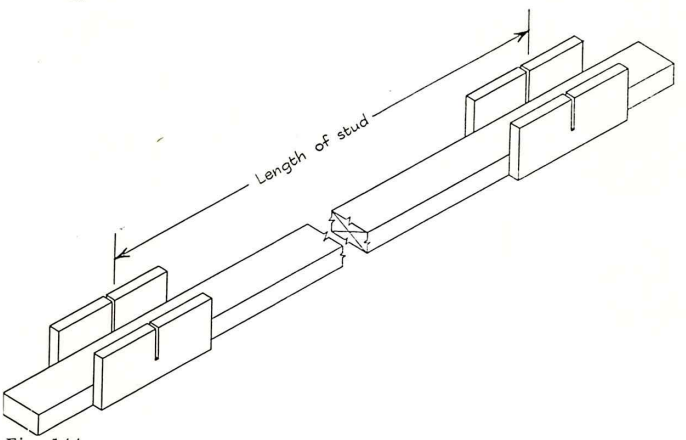


Fig. 144
Simple device for sawing studs to length

Sawing studs to length

Studs may be sawn to a standard length by the use of a device shown in *Fig.* 144, but if a power saw is used the method would vary according to the type of machine.

Assembly of walls

Any of the following methods may be used:

(1) Nailing together on the floor joists the last frames which will be erected, and then assembling the other frames on top of them in their order of erection (i.e., the outside wall frames are assembled on top of the partition frames).

(2) Erection of each frame immediately after its assembly.

(3) Prefabrication in the factory and delivery to the job for erection.

Assembling a frame

The studs are laid in their respective positions with either their rounded or hollow edges upwards. There are varying opinions on which edge should be placed upwards but the main point is to be consistent and place either the rounded or the hollow edges all the same way. Straight studs should be selected for trimmer and for corner studs. All studs are nailed to the plates with 4 in. nails.

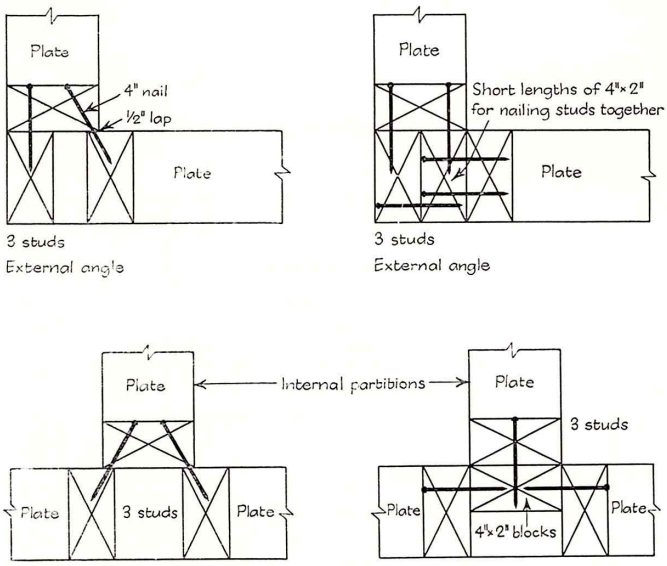


Fig. 145

Arrangement of studs at corners and intersection of walls

Extra studs placed at corners and wall intersections are for additional strength, and also to provide support and nailing for linings. These studs are arranged so that eventual shrinkage and warping of the timber will not cause ugly cracks at the corners, in wall-lining materials, or wallpaper (see *Fig.* 145).

Trimmers and jack studs for door, window, and porch openings

Trimmer studs

The studs on either side of an opening in a wall are known as trimmer studs. When an opening is wider than 4 ft. 6 in. the trimmer studs must be increased in thickness in the proportion of 1 in. for every 4 ft. 6 in. span of the lintel bearing on the trimmer studs. See N.Z.S.S. 1900, Chapter 6.1.)

The horizontal framing timber spanning an opening is known as a "lintel" or "head trimmer" and that across the lower part of an opening a "sill trimmer".

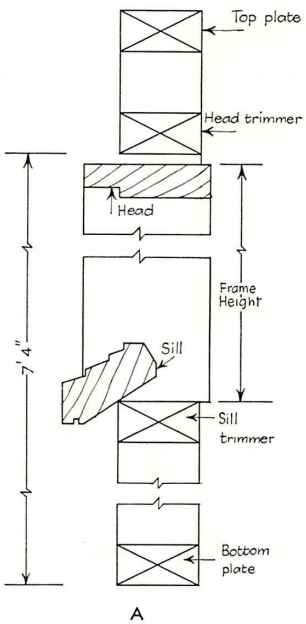
Height of windows

The height of a window may be given in a specification as the height of the head trimmer above the floor joists or the height of the window sill board above the floor. If the head trimmer is 7 ft. 4 in. above the joists the height of the sill trimmer is found by subtracting from 7 ft. 4 in. the effective frame height plus the clearance to be allowed above it (*Fig.* 146A).

Example

	ft.	in.
Effective height of casement frame	4	$8\frac{1}{4}$
Clearance		$0\frac{1}{2}$
Total height	4	$8\frac{3}{4}$

Therefore sill trimmer height = 7 ft. 4 in. − 4 ft. $8\frac{3}{4}$ in.
= 2 ft. $7\frac{1}{4}$ in.



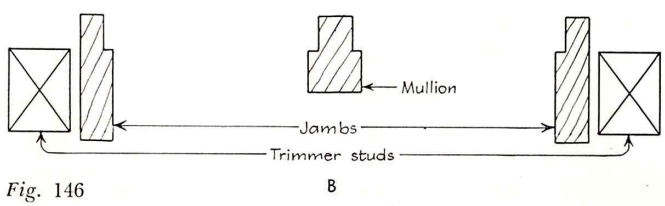


Fig. 146

Window trimmers

(A) *Height of head and sill trimmers for window frame*
(B) *Finding length of head trimmer for two-light casement window frame*

Length of window-head trimmer

The length of a window-head trimmer for a two-light casement window frame, shown in cross section in *Fig.* 146B, is found by adding to the width of the frame the clearances on both sides plus the amount the trimmer is to be housed into each trimmer stud.

Example

Sash width 2 ft. Mullion width $1\frac{5}{8}$ in.
Clearance $\frac{1}{2}$ in. Jamb width $1\frac{1}{8}$ in.

The distance between trimmer studs for a two-light casement window frame is as follows:

	ft.	in.
Clearance		$0\frac{1}{2}$
Width of jamb		$1\frac{1}{8}$
First sash width	2	0
Width of mullion		$1\frac{5}{8}$
Second sash width	2	0
Width of jamb		$1\frac{1}{8}$
Clearance		$0\frac{1}{2}$
Total width	4	$4\frac{7}{8}$

Allowing 1 in. for housing, this would make the length 4 ft. $5\frac{7}{8}$ in.

Height of door-head trimmers (Fig. 147A)

The height of the door-head trimmers from the bottom of the bottom wall plate may be found by adding the heights of the items in the following example:

	ft.	in.
Floor thickness		$0\frac{7}{8}$
Clearance under door*		$0\frac{5}{8}$
Height of door	6	6
Head of door frame (rebated part)		$0\frac{7}{8}$
Clearance between door frame and underside of trimmer		$0\frac{7}{8}$
Total height	6	$9\frac{1}{4}$

Note: With an external door the door sill raises the door frame about $\frac{3}{4}$ in. above the floor so this amount must be allowed for clearance.

Length of door-head trimmers (Fig. 147B)

The length of the trimmer is found by adding the distances as shown below.

Example

	ft.	in.
Clearance – stud and jamb		$0\frac{1}{2}$
Width of jamb		$0\frac{7}{8}$
Width of door	2	8
Width of jamb		$0\frac{7}{8}$
Clearance		$0\frac{1}{2}$
	2	$10\frac{3}{4}$

When the trimmer is housed $\frac{1}{2}$ in. into the studs at each end, its length will be increased to 2 ft. $11\frac{3}{4}$ in.

* The amount of clearance allowed for linoleum floor covering is $\frac{1}{4}$ in. and for carpets $\frac{3}{8}$ in., but this latter figure varies according to the thickness of the underfelt used.

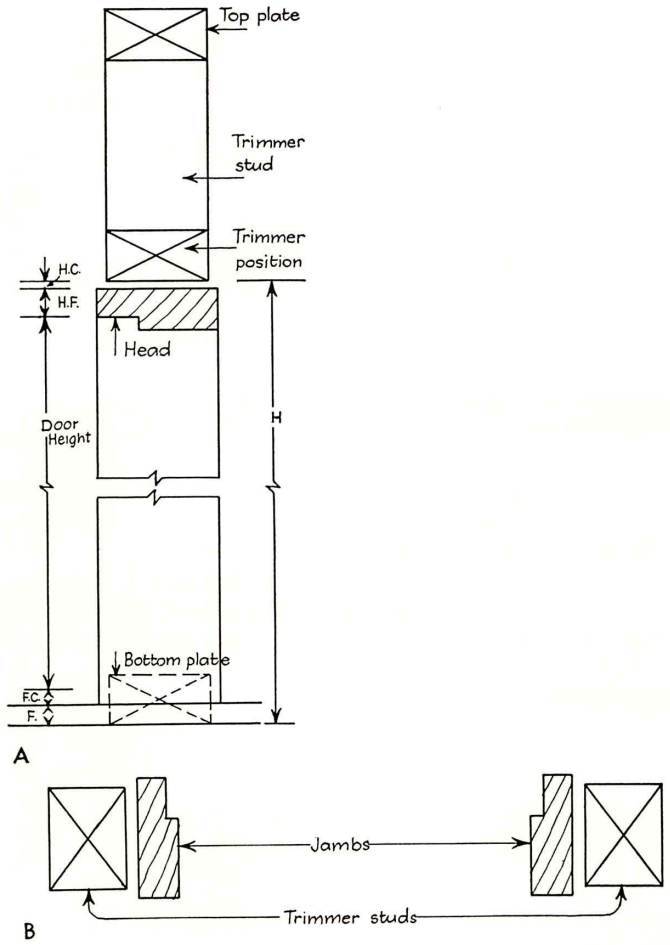


Fig. 147

Door trimmers

(A) *Height of door-head trimmer*
F. = *floor thickness*
F.C. = *clearance of door above floor*
H.F. = *allowance for head of door frame*
H.C. = *height clearance above door frame*

(B) *Finding length of door-head trimmer*

Depth of lintels to openings

The depth of lintels (head trimmers) to openings is given in Table 6 of N.Z.S.S. 1900, Chapter 6.1. This table provides for both solid and built-up lintels and states the amount that lintels must be housed into the trimmer studs. *Fig.* 148 shows how lintels are constructed.

Bracing of walls and partitions

Stud-framed walls are stiffened by means of braces against a tendency to deform or collapse. Particulars of the braces required for walls, bearing partitions, etc. is given in N.Z.S.S. 1900, Chapter 6.1.27. The following is a description of the two principal methods of bracing:

Flush braces (Surface braces)

Lengths of either 4 in. x 1 in. or 6 in. x 1 in. are cut in flush with the outside face of the studs before the

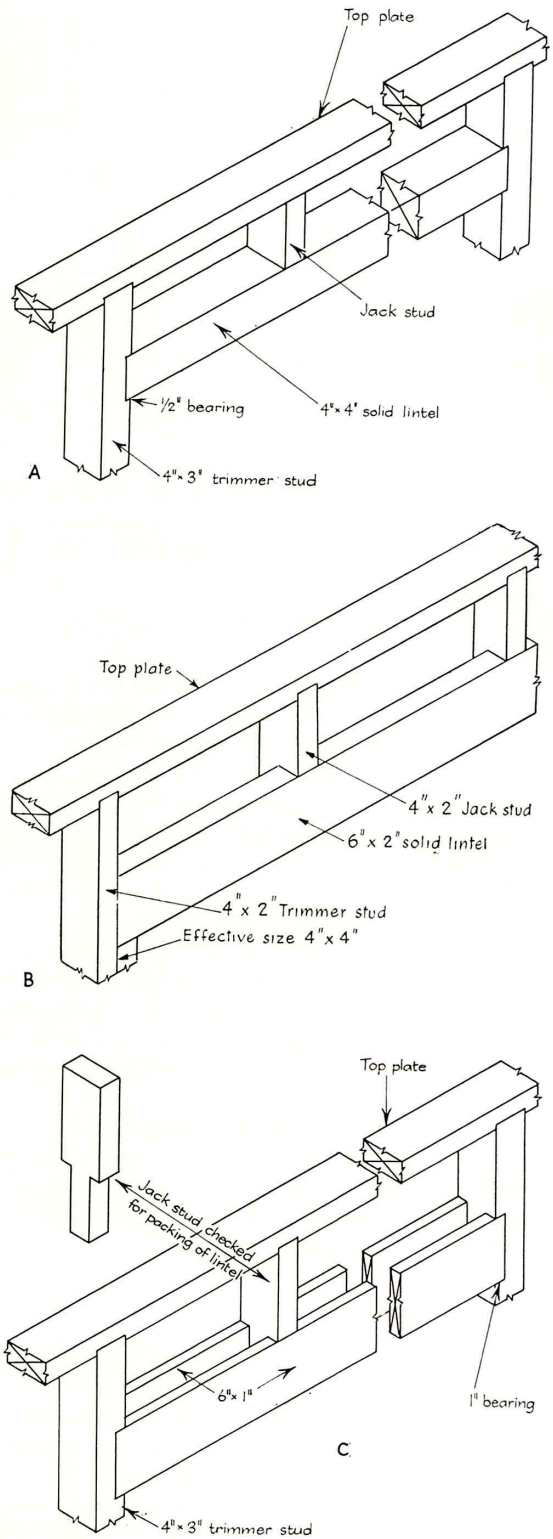


Fig. 148

Lintels

(A) & (B) *Two types of solid lintel*
(C) *Built up lintel*

wall frames are erected. When cutting in braces ensure that the ends of the braces have solid bearing on the plates as shown in *Fig.* 149A.

Solid braces

Solid braces are lengths of 3 in. x 2 in. or 4 in. x 2 in. cut on an angle in between the studs as shown in *Fig.* 149B. The ends of each piece must have solid bearing against either studs or plates; otherwise the brace will be dependent on the holding power of the nails.

Angles of braces

The most effective angle for a brace is 45° and when a wall of a building is longer than 15 ft. there should be two braces so placed as to oppose each other (*Fig.* 150).

In practice it is not always possible to place braces at 45° on account of window and door openings. *Fig.* 149C shows dog-leg bracing, and other methods of bracing are shown in *Fig.* 150.

Bracing in single-storey buildings

Fig. 150 shows the various ways of arranging braces in the walls of a single-storey building.

Bracing in two-storey buildings (*Fig.* 151)

The bracing in each major wall of such a building should if possible extend from the bottom plate to the top plate of the upper storey.

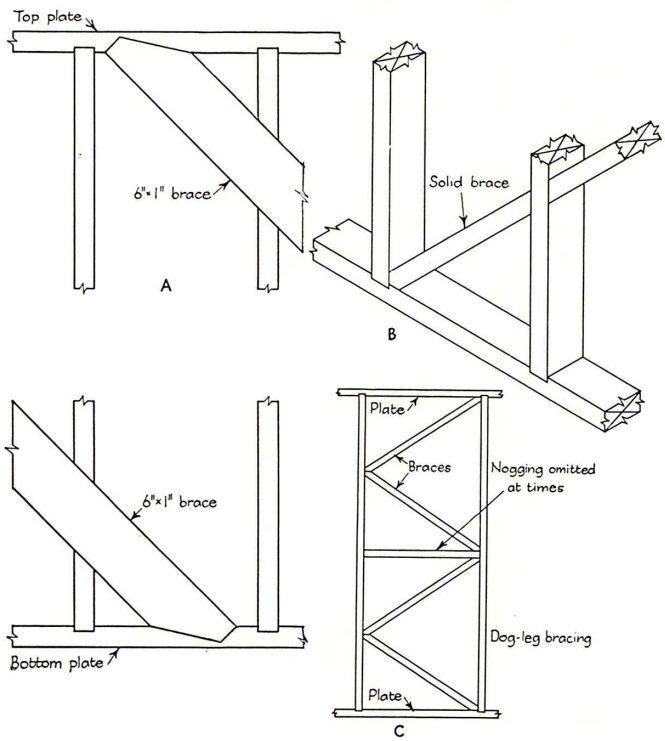


Fig. 149

Methods of bracing framing

(A) *Method of joining flush braces to plates*
(B) *Solid type of brace*
(C) *Dog-leg bracing with solid braces*

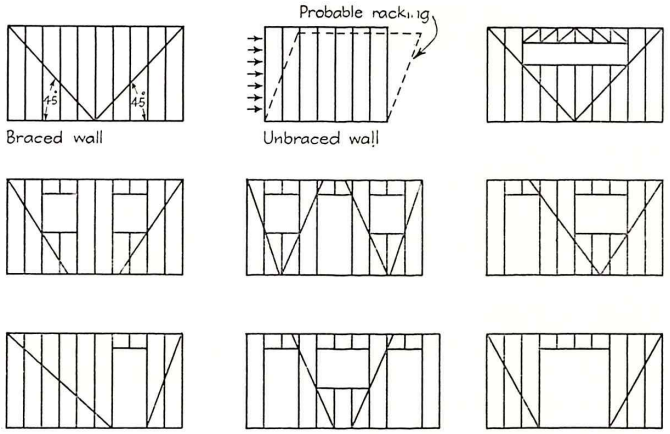
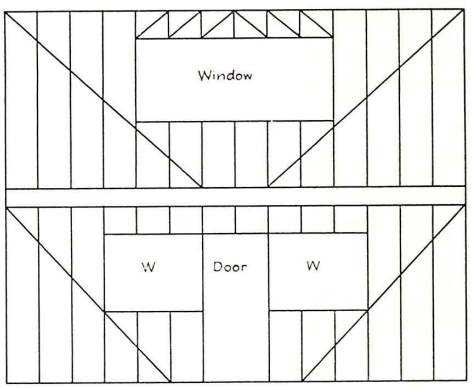


Fig. 150

Methods of bracing framing of single-storey buildings



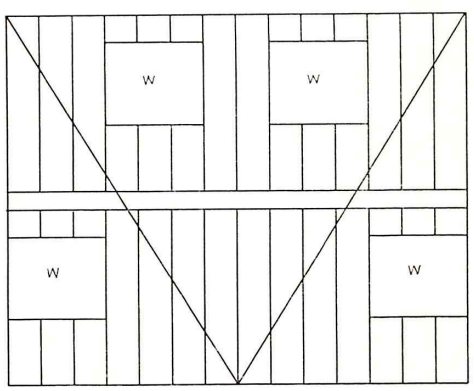


Fig. 151

Two methods of bracing framing of two-storey buildings

Diagonal timbers (*Fig.* 152)

A building is solidly braced and also a rigid backing is provided for sheathing materials when the frame is covered on the outside with diagonal sheathing timbers, which may be closely boarded, or the boards spaced up

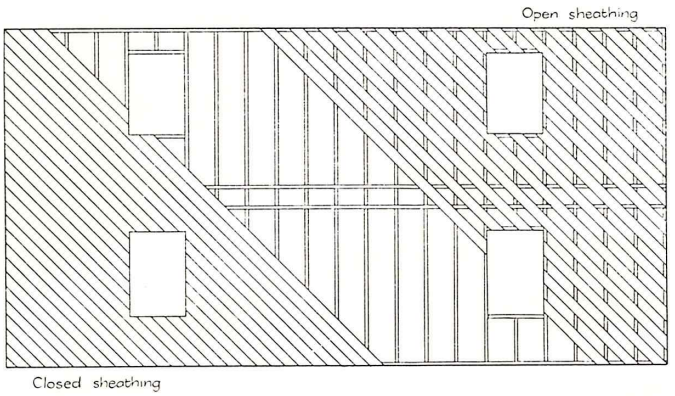


Fig. 152

Diagonal sheathing

to 2 in. apart, and, in some circumstances, a distance of the width of one board apart. When diagonal sheathing is provided ordinary braces are omitted.

Method of squaring wall frames and cutting in a flush brace

When the work of fixing the trimmers and jack studs has been completed the wall frames are first squared and then the flush braces are fitted. (Solid braces are cut in after the frames have been erected.) To square a frame the bottom plate is straightened in its position on the joists and the frame is squared, e.g. by measuring the lengths of the diagonals and then racking the frame until the same measurement is obtained on each diagonal. When a flush brace is to be fitted it is laid on the outside of the framing at an angle of 45° with the top plate. Crooked studs and also the brace must be straightened before it is temporarily secured. The studs are now marked or a saw cut made on either side of the brace, and the cuts arranged on the top and bottom ends of the brace. Studs and plates are now gauged to the thickness of the brace and checked. The brace is placed in position with the lower end left long and it is permanently nailed at the top plate but temporarily at other positions. It is not permanently secured until after the frame has been erected and plumbed.

Erection of wall frames

Assuming all the wall frames have been made up they are erected as follows:

(1) The outside wall frames are raised from the horizontal to a nearly vertical position, with a slight outward lean, and are temporarily strutted. (An outside wall frame at a corner with an inward lean would foul part of the frame subsequently erected on the other side of the corner.)

(2) When the outside wall frames are being erected, the longitudinal halving joints on the wall plates are first joined at the corners and then at intermediate points.

(3) When the corners are fixed to the correct position, the plates must be lined up for straightness between these points. This is usually done by measuring (or gauging with a block of wood about 1 in. thick) from a line stretched from the outside corners. When straight, the bottom plates are nailed to joists, etc., but the top plates must be held straight by means of temporary braces until the ceiling joists have been fixed.

(4) The next job is to plumb the external corners with a plumb-bob and to permanently fix the flush braces to the studs and the bottom plate. (Where the solid braces are to be fixed later, the temporary braces are renailed when the frame is plumb.)

(5) Extra studs that are required at corners and at intersection of walls may now be nailed in place. (The cutting in of dwangs is usually left until later.)

(6) Internal partitions may now be erected. Bearing partitions are first raised in turn to their positions and the half-lap or other joints secured to the corresponding parts of joints on the top plates of other partitions or external walls. When these partitions have been checked for plumb, the bottom plates may be straightened and secured. Finally the flush braces are fixed or solid braces fitted between the studs.

Other partitions are now raised and secured at their top plates. Their bottom plates will eventually rest on the floor and so are temporarily packed above the floor joists with short pieces of flooring boards. These partitions are known as swinging partitions and cannot be secured until the floor has been laid. Partitions for cupboards, wardrobes, etc., are constructed, stud by stud, at any convenient time later.

The above methods of wall framing may be applied to two-storey buildings with slight variations in procedure according to the design.

In two-storey buildings of platform construction the wall framing for the ground floor is erected and, after it has been properly braced and secured, the first-floor joists are fixed, and then wall framing for the upper storey is erected in the manner described for a single-storey building.

Dwangs (*Fig.* 153)

A dwang is a short piece of timber (also known as a nogging) that is fixed between framing members to form a support for the attachment of linings or coverings. All lined stud walls, except those lined with horizontal or diagonal timbers, must have dwangs of 2 in. x 2 in., 3 in. x $1\frac{1}{2}$ in., 3 in. x 2 in., or 4 in. x 2 in. spaced at vertical intervals of not more than 32 in. Dwangs must be arranged so that all edges of lining material have solid support.

The length of a dwang should always be measured near plate level because the distance between the studs varies at different heights owing to the warping of the studs. It is common practice to make a list of the lengths of all the dwangs required and then to saw them from the *shorts* about the job.

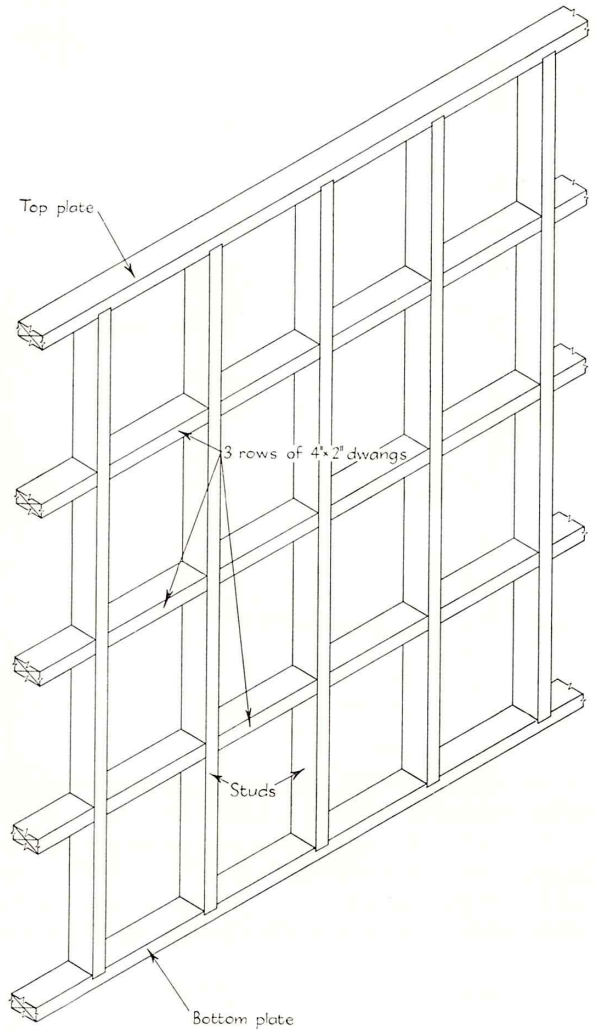


Fig. 153

Rows of dwangs

Straightening studs (*Fig.* 154)

The studs at internal angles and intersecting walls are straightened and nailed together. Before the sheathing is fixed unduly crooked studs should be straightened by making a saw cut about the middle of the crook on the concave side. After the saw cut has been made the stud is pushed straight and a wedge driven in the right amount to straighten the stud. As shown in *Fig.* 154, pieces of timber at least 18 in. long are nailed on the sides of the stud to strengthen it.

Ceiling joists

When all the wall framing has been secured the ceiling joists are usually fixed to tie the walls together. On top

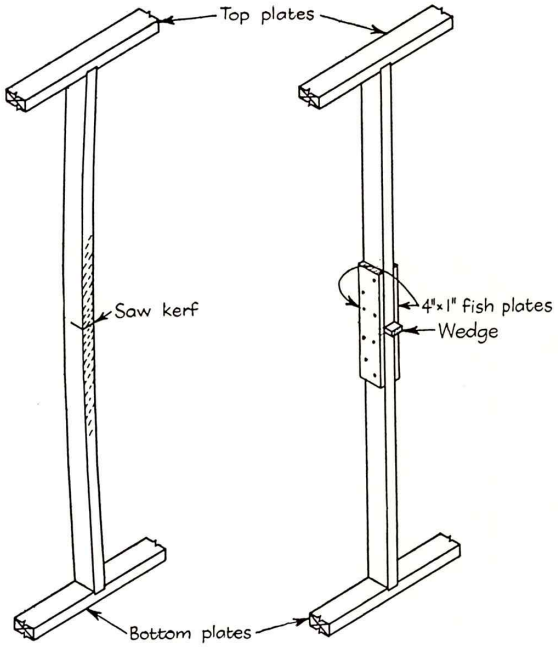


Fig. 154

Straightening a stud

of the ceiling joists (for long spans temporary supports must be arranged) scaffold planks may be laid from which the roofwork construction can easily be handled.

Ceiling joists are usually 4 in. x 2 in., spaced at intervals of not more than 20 in. and placed at right angles to the main ridge. The ends of joists are nailed to the plates and where possible to the feet of rafters, to make a continuous tie across the building. In buildings of more than one storey the joists between storeys serve the double purpose of floor and ceiling joists.

Ceiling joists adjacent to walls

Ceiling joists adjacent to partitions and walls must be so placed as to provide a solid backing for ceiling material and for the cornice or moulding at the angle of the ceiling and wall linings.

A ceiling joist adjacent to an outside wall cannot always be fixed on edge because the lower edges of the rafters prevent this. This joist is either laid on its flat and checked under the rafters, or replaced by short tailing joists lying at right angles to the line of joists between the wall plate and the next joist.

Ceiling runners (Fig. 155)

A ceiling runner is a framing timber used to stiffen and hold ceiling joists in alignment, and also to transfer part of the load of the ceiling to the walls.

The number of runners required on 4 in. x 2 in. joists spaced at 20 in. centres is as follows:

Ceiling joists exceeding 8 ft. in clear span must be secured with one runner in the centre of the span, and ceiling joists exceeding 16 ft. clear span must have two runners evenly spaced.

Runner sizes: 4 x 2 up to 8 ft. span of runner.
5 x 2 up to 12 ft. span of runner.
6 x 2 thereafter.

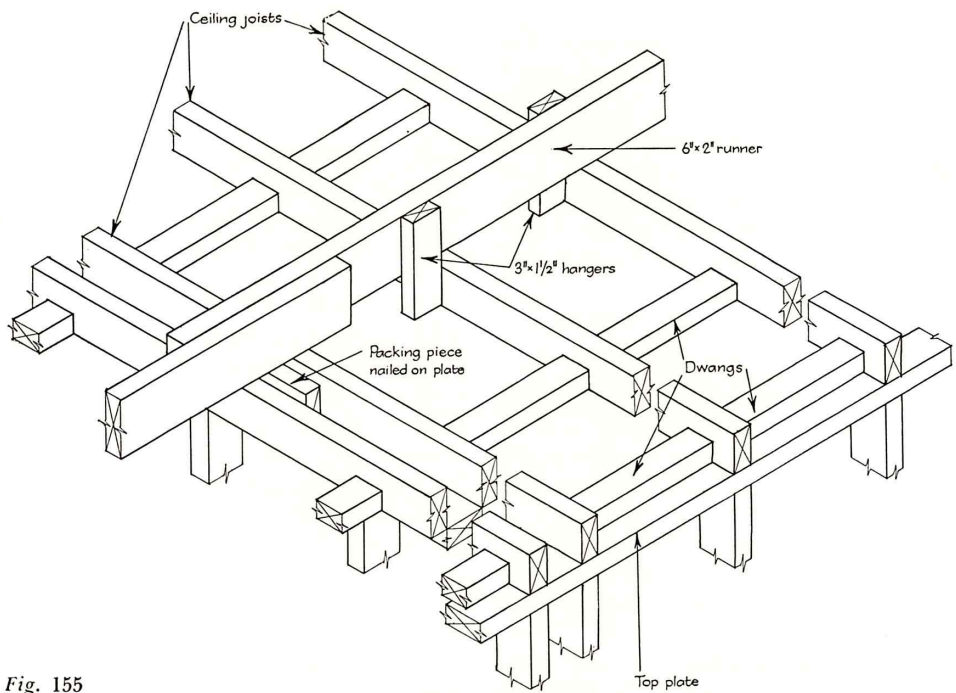


Fig. 155

Ceiling runners

The runners must be lapped on solid bearing and skew nailed from both sides to each joist (*Fig.* 156). Additional support to the ceiling joists is provided by hangers.

Dwangs between ceiling joists

To support ceiling linings, dwangs must be cut between ceiling joists at not more than 3 ft. intervals to suit the sizes of the particular material being used. Alternatively the underside of the ceiling joists may be strapped with $1\frac{1}{2}$ in. x 1 in. battens at 1 ft. centres for soft-board lining and 2 ft. centres for fibrous plaster.

Diagonal braces at ceiling level

Most bylaws require that all external corners of a building must be braced in a horizontal plane at the ceiling level. These braces are fixed to the ceiling joists with their ends secured (at least 6 ft. from corners) to the plates on adjacent walls. *Fig.* 157 shows such a brace in position.

Three ways of fixing such braces are:

(1) Fixing a solid brace across the corner in between the joists.

(2) Fixing a brace on top of the ceiling joist and securing the ends to packing pieces attached to plates (*Fig.* 157).

(3) Fixing a brace across the corner and checking the ceiling joists over it (*Fig.* 158).

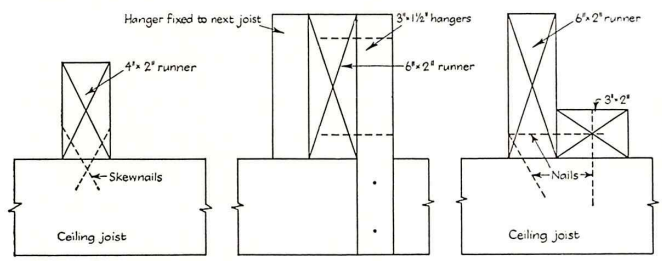


Fig. 156

Methods of securing runners to ceiling joists

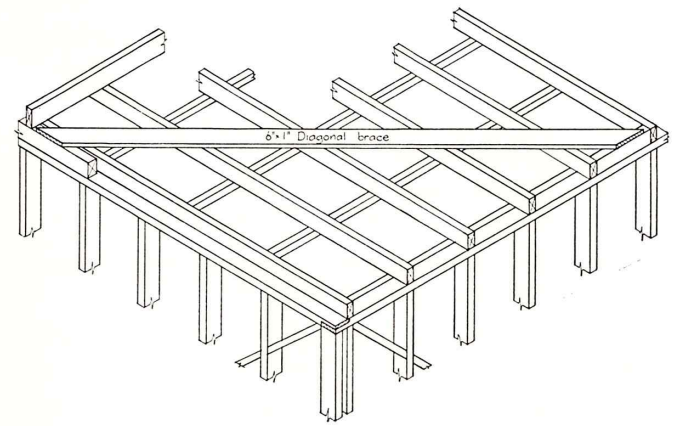


Fig. 157

Diagonal brace over ceiling joists

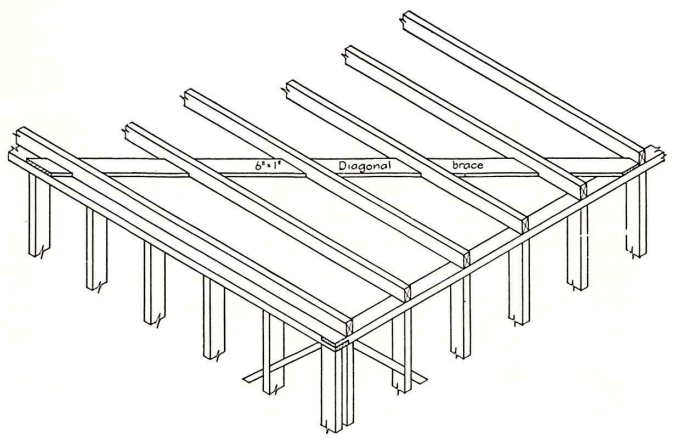


Fig. 158

Diagonal brace under ceiling joists

Questions on Chapter 6

(1) Briefly describe the several processes of:
(a) Assembling the wall frames of a house 45 ft. long and 24 ft. wide.
(b) Checking braces into the studs.
(c) Erecting and securing the wall frames.

(2) Name the grades of exotic and indigenous timber that may be used for wall framing.

(3) Make an isometric sketch of the stud arrangement of an exterior corner of a house.

(4) You are marking out the wall framing and told that 6 ft. 6 in. x 2 ft. 6 in. doors with plain jambs will be used inside and 6 ft. 6 in. x 2 ft. 8 in. doors with solid rebated jambs on exterior walls of the house. In each case calculate the distances between trimmer studs and also the heights of the head trimmers. Allow carpet and underfelt in some rooms and linoleum in others.

(5) Sketch and give dimensions of an opening in an exterior wall for an 8 ft. 6 in. x 4 ft. 8 in. window frame. Show a built-up lintel and state the clearance about the frame.

(6) (a) What is the most effective angle for a wall brace?
(b) Under what conditions may exterior wall bracing of a house be omitted?
(c) How would you place braces between window openings 4 ft. apart?

(7) (a) Explain the differences between the platform and balloon-frame types of construction.
(b) Why is balloon-frame construction not used nowadays?

(8) Show the method of bracing you would use where there is to be a 7 ft. x 7 ft. floor to ceiling window centrally situated in a wall 12 ft. long.

(9) Sketch the method of joining a flush brace to the bottom and also the top plate. Why is the joint made in such a way?

Calculations

(1) (a) How many studs spaced at 1 ft. 6 in. centres would there be in 36 ft. of wall?
(b) How many dwangs 1 ft. 4 in. long can be cut from a piece of 3 in. x 2 in. timber 12 ft. 8 in. long? What is the length of the piece left over?
Allow $\frac{1}{8}$ in. for the width of a saw cut.

(2) What is the length of a diagonal brace for a wall frame 15 ft. long and 8 ft. high?

(3) A room is 12 ft. 6 in. long, 10 ft. 8 in. wide, and 8 ft. 1 in. high. There are two windows, each 4 ft. 6 in. by 4 ft., and a door 6 ft. 6 in. by 2 ft. 8 in. wide. What area of wall is there in the room?

(4) A truck of timber containing 2,100 ft. B.M. cost £84 10s. delivered. The rail freight was £18 7s. What was the cost per 100 ft. B.M. at the mill?

(5) If 4 in. x 2 in. ceiling joists 14 ft. long cost 5s. 6d. each, how much would joists 16 ft. long cost at the same rate?

Chapter 7

ROOFING—ROOFS AND ROOF FRAMING

Roofing

A roof is a structural framework of timber or steel supporting the roof covering of a building. Roofs are sometimes classified according to shape or according to the covering materials, but the most important basis of classification is the arrangement of the structural members.

Couple roof (*Fig.* 159)
A couple roof is composed of pairs of rafters not tied at their lower ends. Such a roof must have specially designed walls to resist the thrust of the rafters.

Couple-close roof (*Fig.* 160)
A couple-close roof is a couple roof with pairs of rafters tied together at their lower ends to prevent the spreading of the roof.

Collar roof (*Fig.* 161)
A collar, or collar-tie, roof is a couple roof with a horizontal member known as a collar-tie fixed between opposite rafters at about half the height of the roof.

Couple-close and collar-tie roof
This roof is most commonly used for dwellings and is a combination of the couple-close and collar-tie types of roof. *Fig.* 162 shows a typical example of such a roof.

Typical house roofs
In residential construction work roofs are divided into simple framed roofs and trussed roofs.

Simple framed roofs for dwellings
Roofs for dwellings are commonly named according to their shape such as a lean-to, a flat, a hip, a gable, or combinations of these shapes.

Flat roof (*Fig.* 163)
A flat roof is one with a roof surface horizontal or nearly so. N.Z.S.S. 1900, Chapter 6.1, defines a flat roof as one with a slope of less than 1 ft. in 6 ft.

Lean-to roof (*Fig.* 164)
A lean-to roof is one with the rafters sloping in one direction. Such a roof enclosed by parapets is known as a hidden lean-to, or parapet, roof.

Gable roof (*Fig.* 165)
A gable roof is a pitched roof that terminates in a gable. A gable is an outside end wall of triangular shape between the ridge and the line of the eaves.

Hip roof (*Fig.* 166)
A hip roof is one that is inclined at the ends as well as the sides. It is without a gable.

Note: When pitched roofs cover areas with offsets, valleys are formed at the intersection of the roof surfaces (*Fig.* 167).

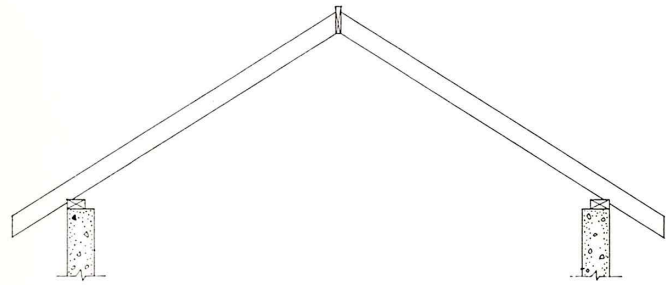


Fig. 159
Couple roof

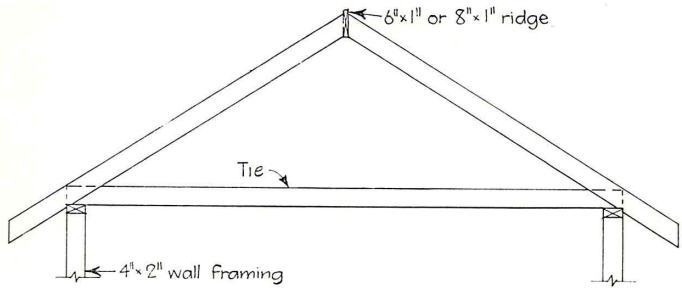


Fig. 160
Couple-close roof

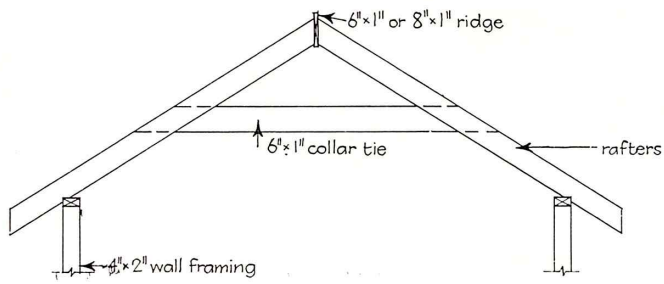


Fig. 161
Collar roof

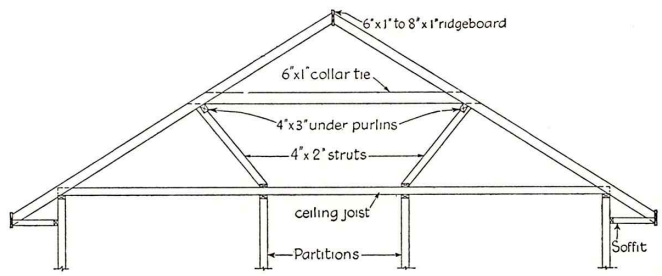


Fig. 162
Couple-close and collar roof

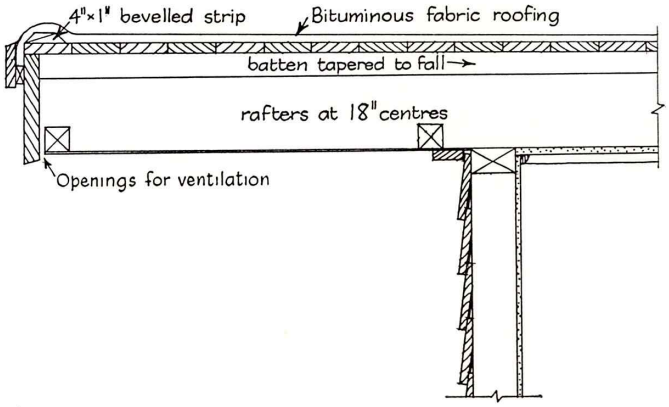


Fig. 163

Overhang of a flat roof

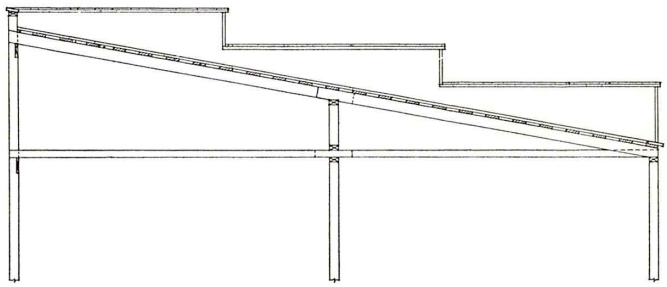


Fig. 164

Lean-to roof

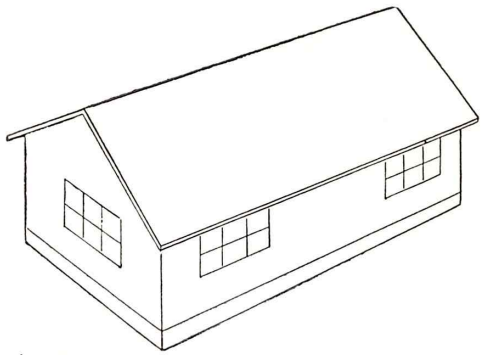


Fig. 165

Gable roof

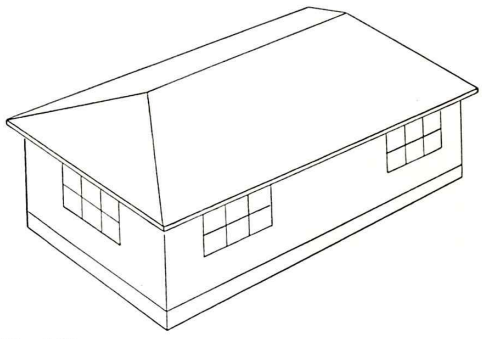


Fig. 166

Hip roof

Trussed roofs

A truss is a self-contained triangulated rigid frame of wood or steel arranged and designed to transfer the loads acting on the frame to the supports (*Fig.* 168).

The shape of the truss and the size of its members depend upon the span and other requirements. Trussed roofs are now frequently used on dwellings as well as on commercial and public buildings.

Roofing terms

The following roofing terms should be carefully noted and memorised.

Span

The span of a roof is the horizontal distance across the building from the outer edge of one wall plate to the outer edge of the other (*Fig.* 169).

Run

The run of a roof is the horizontal distance from a plumb line through the centre of the ridge to the outer edge of one wall plate and, in equal pitch roofs, is equal to one-half of the span (*Fig.* 169). Compare the run of an equal pitch roof (*Fig.* 170A) with one of unequal pitch, as shown in *Fig.* 170B.

Rise

The rise of a roof is the vertical distance as shown in (*Figs.* 169, 171). This distance is measured either from the top edge of a rafter or from a pitch line parallel to its edge. Both distances are the same.

Inclination of a roof (Fig. 172)

The inclination of a roof to the horizontal may be expressed as follows:

(1) *Pitch:* The pitch of a roof is the ratio of the rise and span of the roof $\left(\frac{\text{rise}}{\text{span}}\right)$ and is always expressed as a fraction, e.g., $\frac{1}{4}$, $\frac{1}{3}$, $\frac{1}{2}$. A roof with a span of 24 ft. and a rise of 8 ft. will have a pitch of $\frac{8}{24}$ i.e. $\frac{1}{3}$.

Rule: To find the pitch of a roof divide the rise by the span.

(2) *Inclination expressed as rise in inches per 12 in. run*

The inclination of a roof can be expressed in terms of

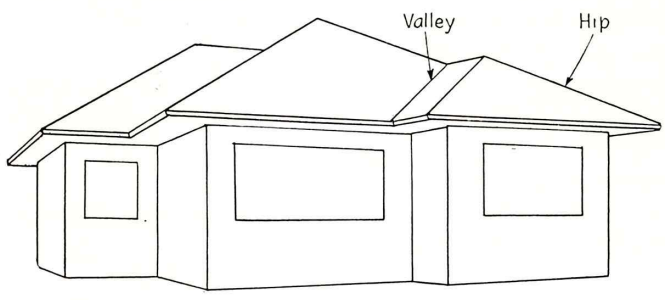


Fig. 167

Hip and valley roof

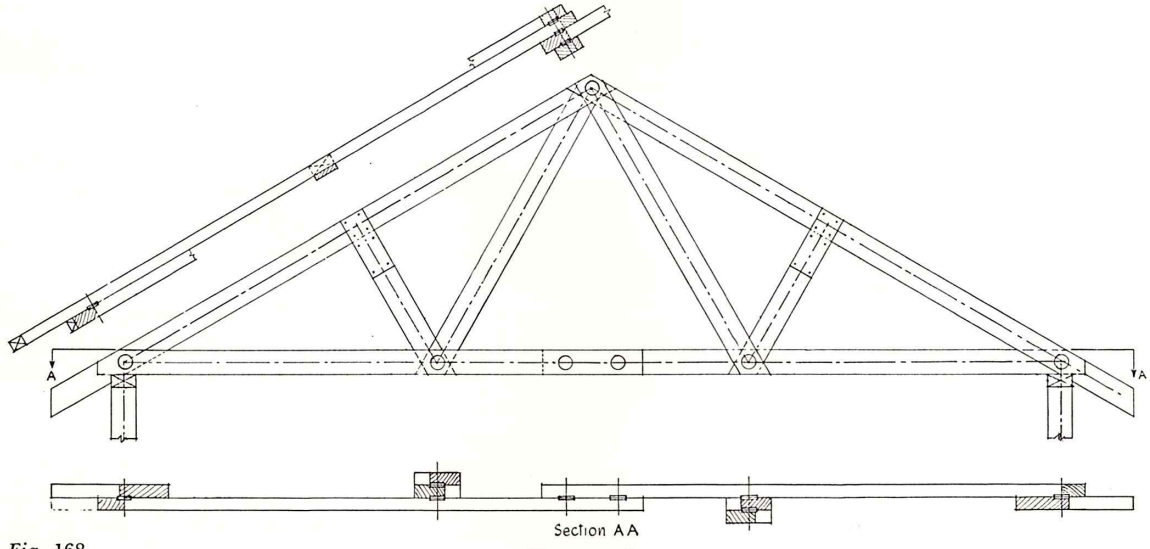


Fig. 168 ***Truss roof***

inches of rise per 12 in. run. When, for example, a roof rises 8 in. for every 12 in. of run, over 24 in. of run it will rise 16 in., and in a roof with a run of 10 ft. it will have a rise of 6 ft. 8 in. $\left(\frac{120}{12} \times \frac{8}{1} = 6 \text{ ft. } 8 \text{ in.}\right)$.

Fig. 172 shows the relationship between pitch and rise in inches per 12 in. of run.

(3) *Inclination expressed in degrees*

The angle of the inclination of a roof with the horizontal is frequently expressed in degrees, as for example, 25° or 32°. An inclination of 32° is equivalent to a rise of $7\frac{1}{2}$ in. per foot of run.

Common roof pitches

A pitched roof is one with inclined surfaces, in contrast to a roof with a flat or nearly flat surface. New Zealand Standard Specification 95, Part IX, classifies a pitched roof as one with an inclination of 1 in 6 or greater. The type of roof covering has a bearing on the pitch that may be used; for example, with a tiled roof, the pitch should not be less than about $\frac{1}{3}$.

Equal and unequal roof pitches

An equal pitch roof has the same inclination for all its parts but an unequal pitch roof has two different inclinations. (*Fig.* 170.)

Roofing members (Fig. 173)

Member

A member is a piece of structural framework, such as a rafter, ridge, etc.

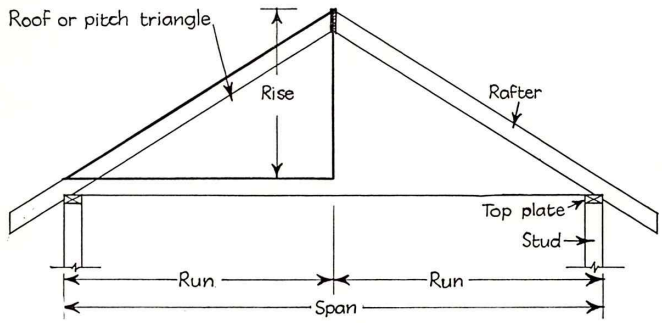
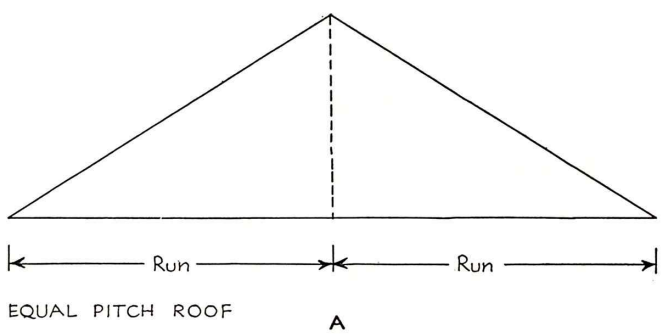


Fig. 169 *Span and run of a pitched roof*



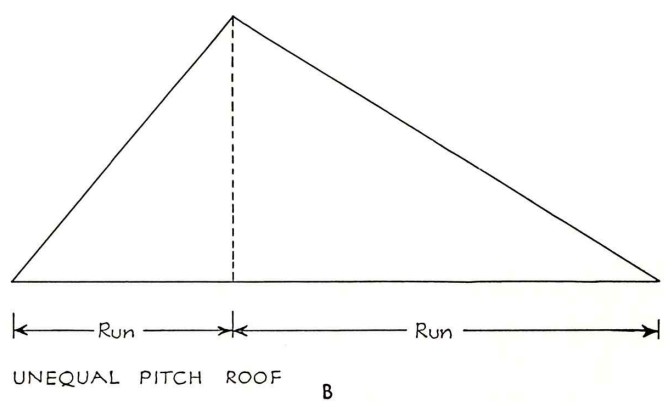


Fig. 170
Roof pitch
(A) *Equal-pitch roof*
(B) *Unequal-pitch roof*

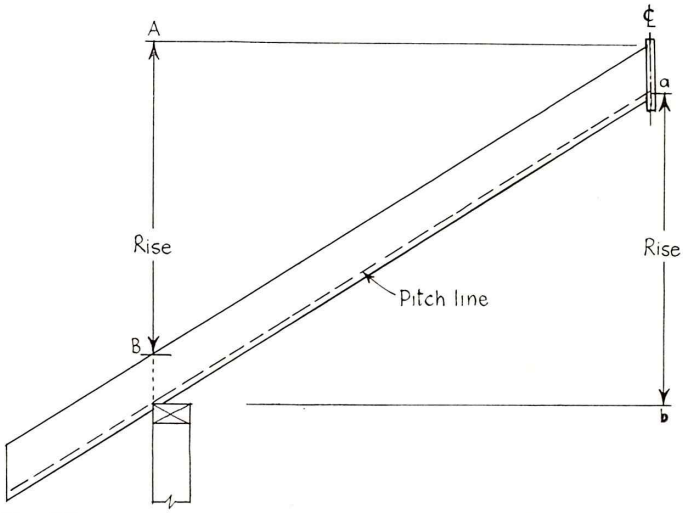


Fig. 171
Rise of a roof (two methods of measuring shown)

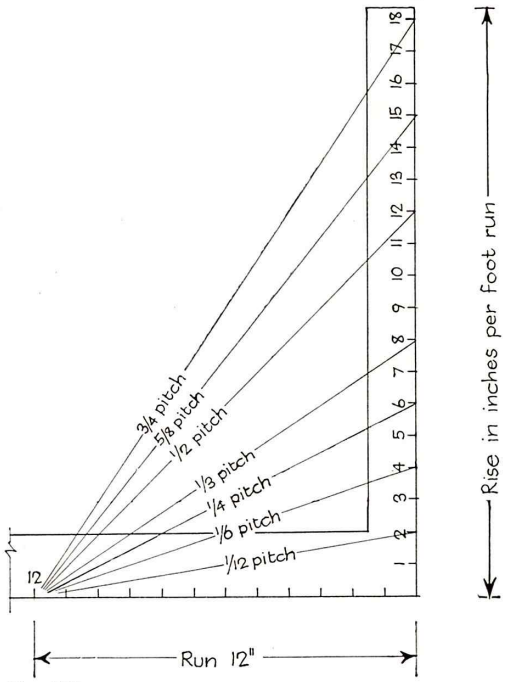


Fig. 172
Diagram shows relationship between run, rise, and pitch

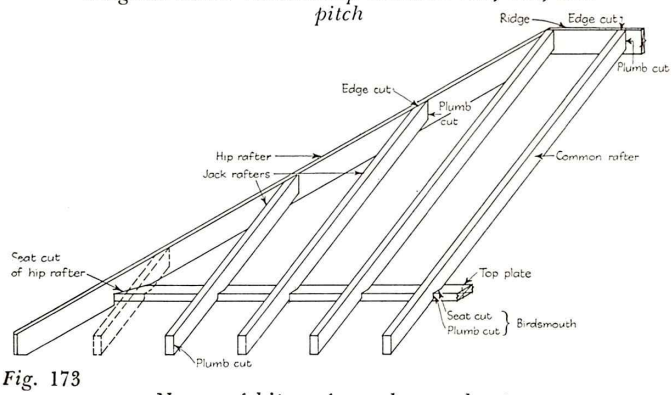


Fig. 173
Names of hip-roof members and cuts

Top plate
The top plate is the horizontal timber placed across the top ends of studs to which the lower ends of rafters are fixed.

Rafters
Rafters are framing timbers extending in a direction at right angles to the lines of the eaves, ridge, and purlins, providing support for purlins or sarking and roof covering, Common, hip and jack rafters are shown in *Fig.* 173.

Purlins
Purlins are horizontal framing timbers fixed across the tops of rafters to support roof coverings. Purlins may also be placed under rafters as a means of support and are then known as under-purlins.

Tile battens
Tile battens are the 2 in. x 1 in. timbers fixed at right angles to the rafters (on the top side) for the purpose of fixing tiles. These tile battens are fixed at spacings to suit.

Sarking
Sarking consists of boards fixed across rafters as a support for the roof covering. Sarking may be either open or close boarded depending upon the type of roof covering that is used.

Struts
Struts are members bearing compressive stresses. In light timber construction, the term strut is given to the member which transmits load from the rafters or purlins down to a partition or some other suitable support.

Collar ties
Collar ties are horizontal timbers above plate level tying opposite rafters, or rafters and studs in the case of a lean-to roof.

Ridges
Ridges are horizontal boards to which the top ends of common rafters are fixed.

Roofing cuts (Fig. 173)

Cut
The term "cut" refers to the angle at which a piece of timber is sawn and in using this word the direction and position of the cut are frequently given, i.e. (1) hip rafter plumb cut, (2) common rafter seat cut.

Plumb cut
A plumb cut is any vertical cut on a rafter in position.

Face cut
A face cut is one that is marked on the side of a rafter.

Edge cut
An edge cut refers to a mark made on an edge, or narrower surface, of a rafter.

Birdsmouth
The birdsmouth is formed on the lower edge of a rafter where it fits over the top plate and requires a horizontal and a plumb cut.

Seat cut

The horizontal cut of a birdsmouth is also known as a seat cut and is always at right angles to the plumb cut.

Backing angle

This term is applied to the bevelling of the top edge of a hip rafter to conform with the slope of the roof so that the ends of the sarking boards or tile battens will seat firmly. The backing angle refers to the particular bevel or angle to which the top edge of the hip rafter is shaped.

Reading a roof plan

A plan of a roof is usually a single line diagram with each line in the plan representing the centre line of the edge of a roof member, except in the case of wall plates, where the lines represent the outside edges of the plates. In an elevation the lines represent the top edges of rafters.

Setting out a roof

Before the parts of any roof may be cut and assembled we must have the following information:

(1) The lengths of the different rafters.
(2) The amount of the overhang (if any).
(3) The angles of the various cuts.
(4) The position and shape of the cuts.
(5) The distance by which a rafter must be reduced in length (shortened) to allow for part of the thickness of the member against which the rafter is framed.

Finding lengths and bevels of roof members

The lengths and bevels of roofing members in a pitched roof may be found by any of the following methods:

(1) Geometrical.
(2) Steel square.
(3) Trigonometrical.
(4) Arithmetical.
(5) Special tables.

The above methods are all based on geometrical principles and it is important that the reader should be familiar with the geometrical method before proceeding with any of the others.

Geometrical method No. 1

The geometrical method may be demonstrated in several ways, but we shall confine our description to one where either true lengths of roof members from an elevation or vertical section are projected down to a plan, or conversely, the true lengths from a plan are projected up to an elevation or vertical section.

Right-angled triangles

The right-angled triangle is the basis of all roof geometry and incidentally roof framing. Shown in *Fig.* 174A is a right-angled triangle which forms the outline of a lean-to roof in *Fig.* 174B. It will be seen that the base of the triangle represents the run of the rafter, the altitude of the triangle, the rise of the rafter, and the hypotenuse of the triangle, the length of the rafter from the centre of the ridge to the outside edge of the wall plate. When two right-angled triangles are placed in position, as shown in *Fig.* 175, they form the outline of a pitched roof. Shown in *Fig.* 176 are some of the right-angled triangles in a roof. A careful study of this diagram will prove of advantage.

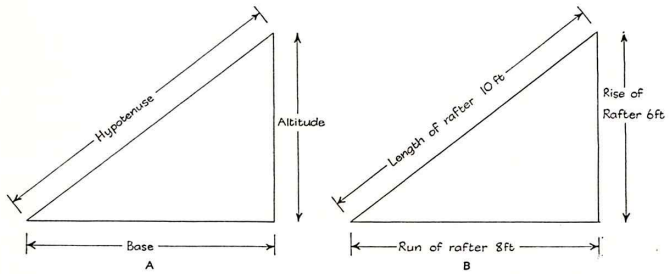


Fig. 174

Comparison between right-angled triangle and section of lean-to roof

(A) *Right-angled triangle.* (B) *Outline of lean-to roof*

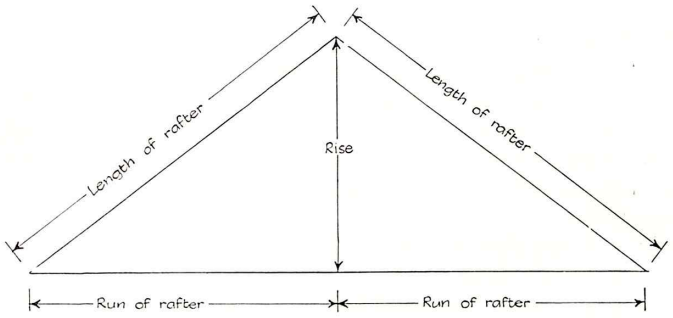


Fig. 175

Two right-angled triangles forming shape of gabled roof

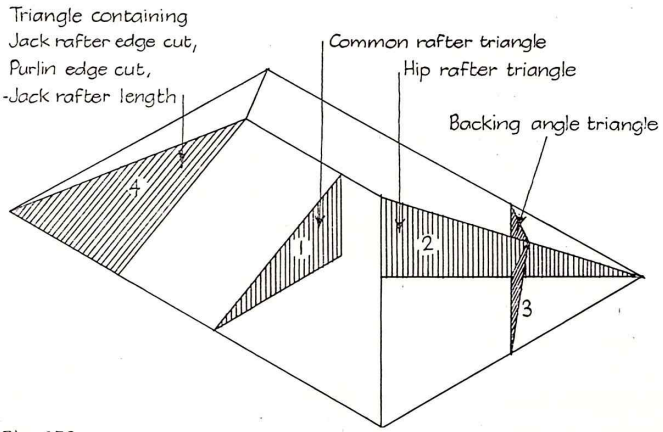


Fig. 176

View of right-angled triangles in hip roof

Common rafter

Length and cuts of common rafter

From the plans and specifications of a building we find the span and the rise of the roof, and then draw a single line plan (or part plan) and cross section through the roof (*Fig.* 177).

When the walls of a building are parallel and of equal height and the ridge is centrally placed, all common rafters have the same length and cuts.

The right-angled triangle No. 1 in *Fig.* 176 is the triangle from which the length and cuts of the common rafter are obtained. *This right-angled triangle has adjacent sides equal to the run and rise of the common rafter. Fig.* 177 shows a cross section of the roof formed of two common rafter triangles drawn to scale, the adjacent sides of each triangle being represented by the rise and run (half-span) of the common rafters. The length of the hypotenuse of each triangle is the scale length of a common rafter from the centre line of the ridge to the outside edge of the wall plates. That portion of a rafter overhanging the wall must be added to obtain the full length of the rafter.

A bevel may be set to the plumb and seat cuts as shown and applied to the actual rafter.

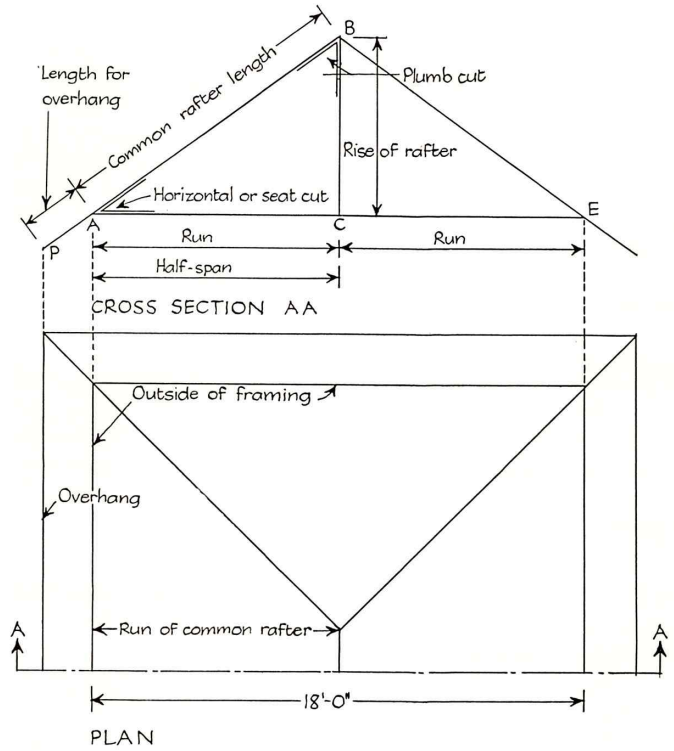


Fig. 177

Part plan and cross section through the roof showing length ana cuts of common rafter

Shortening of common rafter

As previously explained, roof members are represented on a plan as single lines which may be measured for length, but when thickness is given to members certain reductions, or shortenings, must be made to the lengths of the various members. The common rafter must be shortened to allow for half the ridge thickness, and in *Fig.* 178 the line AB is the distance by which the rafter is shortened. Regardless of the pitch of the roof, the rafter is always shortened by measuring the distance AB at right angles or square from the plumb cut of the rafter.

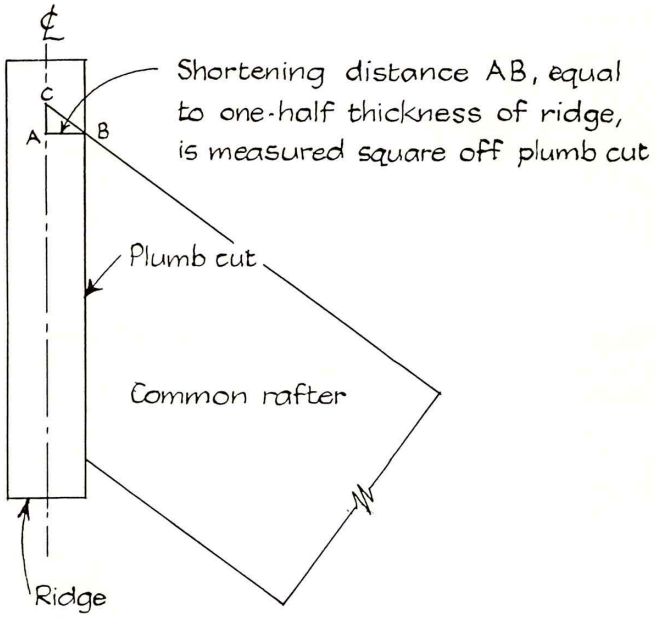


Fig. 178

Cross section through ridge showing shortening of common rafter

Hip rafter

Hip rafter length and cuts

This rafter triangle is a right-angled triangle having adjacent sides equal to the run and rise of the hip rafter (*Fig.* 176, No. 2).

To draw this triangle (*Fig.* 179) we obtain the run of the hip from the plan and draw from this a vertical section through the hip. The scale length of the hip rafter may then be measured. With centre A′ on the plan and A′D′ as radius, describe an arc from D′ cutting A′L at H. This distance A′H is equal to the run of the hip. The hip rafter has the same rise as the common rafter; therefore, in the elevation, a line is projected horizontally from B. From the point H in the plan a line is projected vertically upwards to cut this horizontal line at D. Join DA. This line represents the scale length of the hip rafter, *exclusive* of overhang. The run of the hip rafter overhang is represented in the plan by the

line A′R. This distance is projected to the vertical section by taking A′ as centre and A′R as radius and describing an arc from R to cut LA′ produced to Y′. From Y′ a line is projected vertically to cut DA produced to Y. The length of the line DY is the scale length of the hip rafter, *inclusive* of the overhang.

The angle DAK is the hip rafter seat cut and ADK is the hip rafter plumb cut.

Edge cut of hip rafter

The edge cut for the hip rafter is set out on a part plan of the corner of the building as shown in *Fig.* 180. The right-angled triangle containing this edge cut cannot be shown in *Fig.* 176 but it may easily be seen in *Fig.* 180 i.e., the triangle ADC *whose adjacent sides are proportional to the length and run of the hip rafter.* The edge cut is found by drawing a part plan and section as shown. With centre D′ and D′B′ as radius, describe an arc cutting D′K at C′. D′C′ is then the true length of D′B′ in a horizontal plane (plan). Project D′ and C′ down to the centre line of the hip extending DB to C. Join A to C and E to C which are the true lengths of the hip edge cut abutting against the common rafters. The right-angled triangles ADC or EDC contain the edge cut of the hip, i.e. the angles ACD or ECD.

Shortening hip rafter

The distance that any hip rafter is shortened will depend on the construction at the apex of the roof. When the

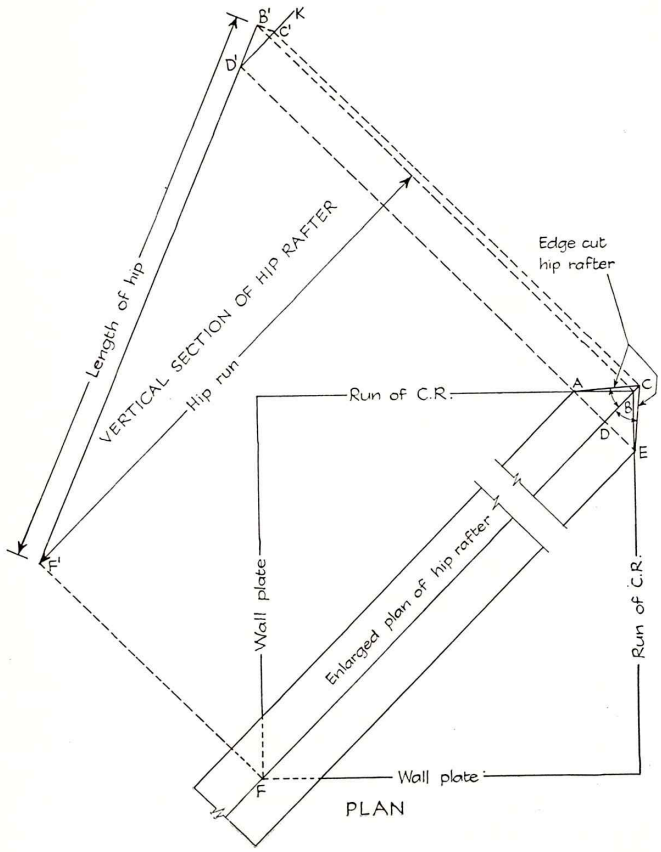


Fig. 180
Part plan and section of hip rafter showing edge cuts of hip rafter

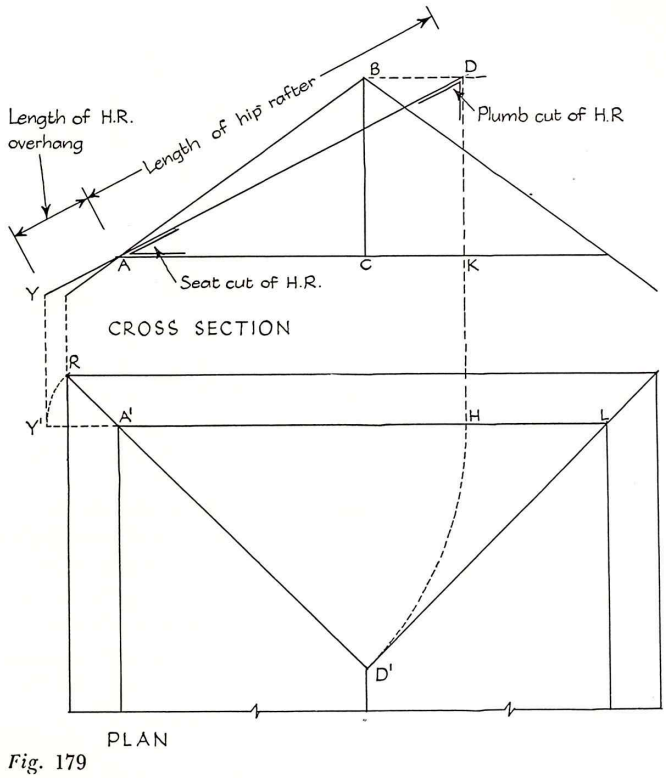


Fig. 179
Part plan and cross section through the roof showing length and cuts of hip rafter

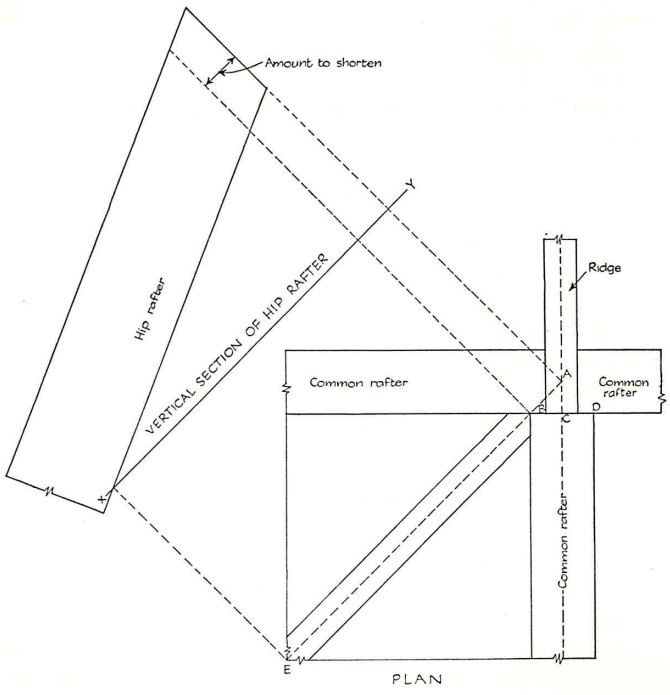


Fig. 181
Part plan and section of hip rafter showing shortening of hip rafter

hip rafter is framed against the common rafters and ridge as shown in *Fig.* 181 it will be seen that the length, based on centre lines, must be reduced by the distance AB to allow for the thickness of these rafters. The line AB is the hypotenuse of a right-angled triangle, the sides being AC and BC, both of which are equal to one-half the thickness of the common rafter. As this distance is known, the length of AB may be easily found by drawing a right-angled triangle with adjacent sides equal in length to AC or BC and then measuring the length of AB, which represents the distance the hip rafter must be shortened. In an actual case where the common rafter is 2 in. thick, a triangle would be drawn with adjacent sides 1 in. long and the hypotenuse when measured, would be $1\frac{7}{16}$ in. bare, which would be the shortening distance.

Actually AB is half the length of a line drawn across the common rafter at 45°.

Hip backing angle

Fig. 182 shows the plan and a vertical section of a hip rafter with the line GF representing the plan of the hip rafter. From any point X′ in the vertical section, a line is drawn at right angles to G′E and cuts the XY line at V′. This represents a vertical section through the right-angled triangle 3 in *Fig.* 176. The true length of X′V′ is projected on to the plan by describing an arc (with V′ as centre and V′X′ as radius) which cuts the XY line at R and from here is projected to X on the plan. The point V′ is projected to T and U and TX and U are joined.

The angle TXV, or UXV, is the hip backing angle being the right-angled triangles TVX and UVX and *having adjacent sides proportional to the length and rise of the hip rafter.*

Note how the backing angles are marked on the top edge of a hip rafter.

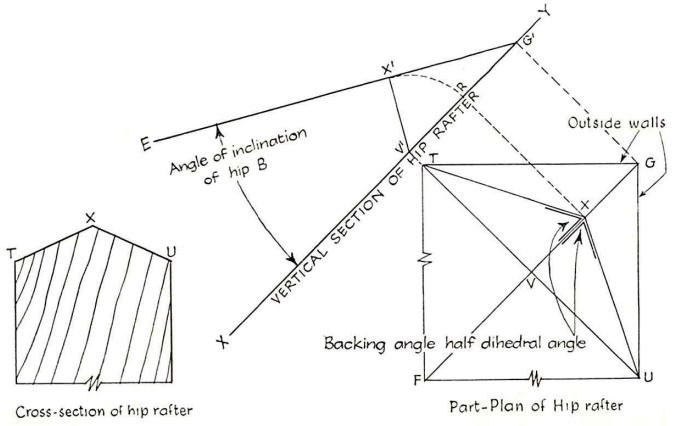


Fig. 182

Part plan and section of hip rafter, showing backing angle of hip rafter

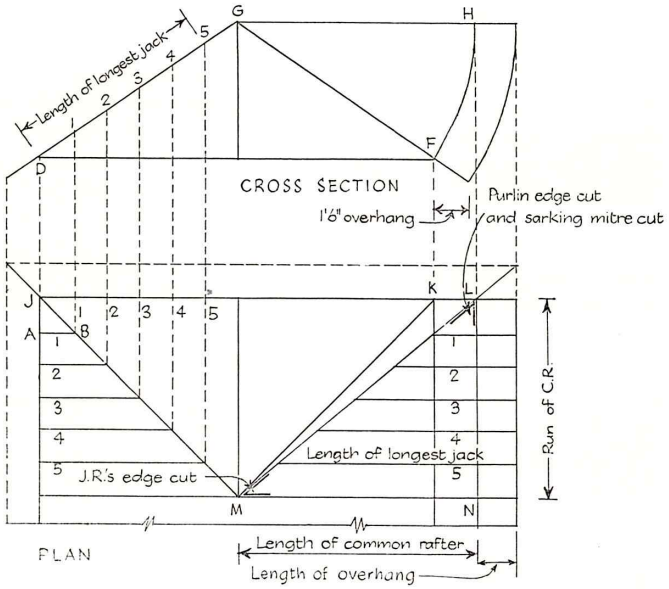


Fig. 183

Part plan and section through roof, showing length and cuts of jack rafters

Jack rafters

The seat and plumb cuts of jack rafters are the same as those of common rafters but the edge cut is different. In *Fig.* 183 it will be seen that the run of each jack rafter is different and consequently the jack rafters will have varying lengths.

To determine the lengths of jack rafters the following two methods may be used:

Method (1) To determine the length of jack rafter No. 1 shown on the left-hand side of the plan (*Fig.* 183), project a line vertically from B to cut DG in the elevation of the common rafter. The distance from D to 1 measured up the slope of the rafter is the length of the jack rafter No. 1. The lengths of the other jacks are found by measuring from D to the numbered points shown. The difference in length between the common rafter and the longest jack, or any two jacks, is known as the *diminish* of the jack rafter.

Method (2) Both the lengths and cuts for jack rafters may be obtained by this method. Refer back to the right-angled triangle numbered 4 in *Fig.* 176. This is the triangle from which the lengths of the jack rafters are obtained as well as the edge cut for the jack rafters, and the edge cut for the purlins, To make a plan of this triangle, the true length of the common rafter must first be projected down on to the plan. Starting from point G in the elevation (*Fig.* 183) and with this point as centre and GF as radius describe an arc to cut the horizontal line from G at H. Project H down to the plan to cut JK produced at L; continue HL to cut a line from M parallel to JK at N. Join ML.

The triangle LNM is the development of the inclined roof surface. The scale length of the hip rafter is represented by the line ML, MN is the scale length of the

common rafter, and the scale lengths of the various jack rafters may be measured from the plan. The angle MLN, besides being the edge cut for the purlins, is also the mitre cut for the sarking boards. The angle NML is the jack rafter edge cut.

It will be seen that *the right-angled triangle LNM containing the purlin edge cut and the jack rafter edge cut has adjacent sides equal to the length of the common rafter and the run of the common rafter;* i.e., LN is equal to the run of the common rafter and MN is equal to the length of the common rafter.

Shortening jack rafters

On the plan, *Fig.* 184, jack rafters meet the hip at an angle of 45° and are shortened by the distance AB, which is the hypotenuse of the triangle ACB. *This distance AB must be measured square off the plumb cut.* The lengths of the adjacent sides of this triangle are each equal to half the thickness of the hip rafter. In an actual case with a hip rafter 1 in. thick, a right-angled triangle would be drawn with adjacent sides of $\frac{1}{2}$ in. The length of the hypotenuse would be $\frac{11}{16}$ in. full, which would be the shortening for the jack rafters.

The length of AB is really half the length of a line marked at an angle of 45° across the edge of the hip rafter.

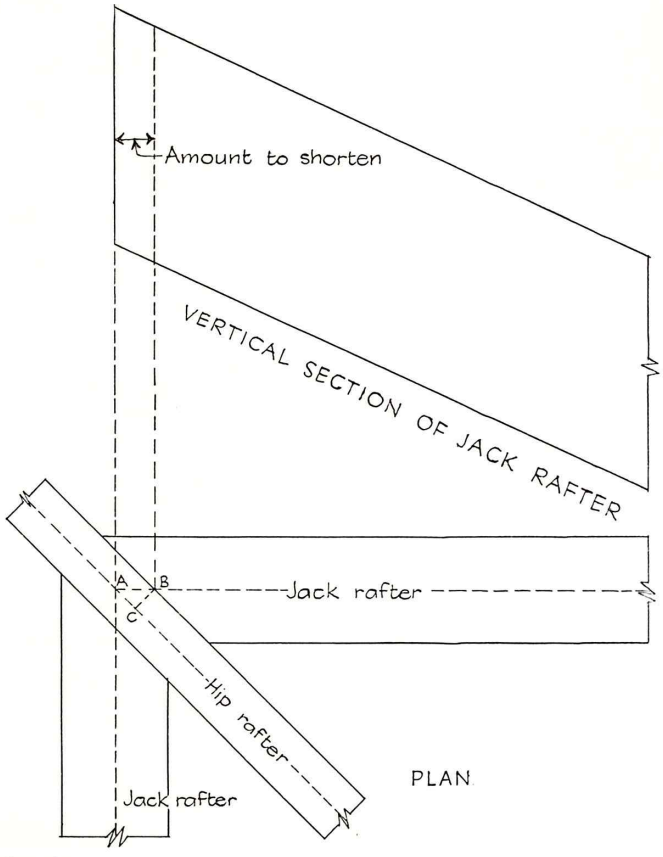


Fig. 184

Part plan and section of jack rafter showing shortening of jack rafter .

Purlin cuts

The cuts of purlins are obtained by developing or turning the sides and edges of purlins as seen in section until they are horizontal, and then projecting these true lengths to the plan. *Fig.* 185 shows a vertical section of a purlin and the part plan of the purlin and the hip rafter. To develop the cuts for the purlins, through A, in the vertical section, draw a horizontal line DI. With centre A and radius AB describe an arc DB, and with radius AC describe an arc CE. By this means the purlin has been developed or opened so that DA equals AB and AE equals AC, the side and edge of the purlin respectively. Project downwards the points D, A, and E to cut the plan of the purlin. The side and edge cuts are as shown. *The right-angled triangle A'KD' has adjacent sides proportional to the length and rise of the common rafters, and the right-angled triangle A'ME' has adjacent sides proportional to the run and length of the common rafter.*

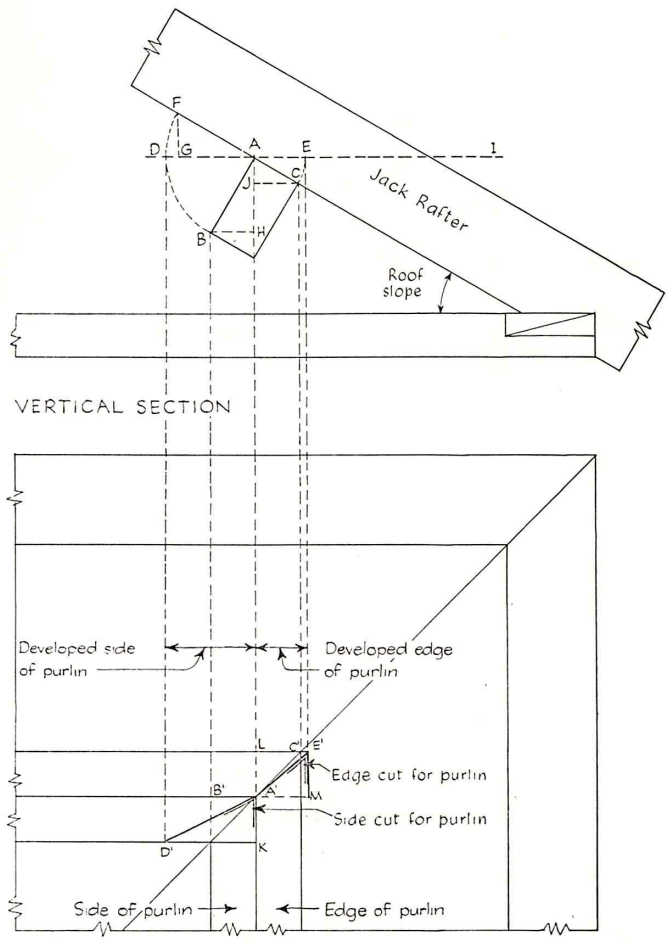


Fig. 185

Part plan and cross section of purlin showing purlin cuts

Valley rafter

A valley rafter is the hypotenuse of a right-angled triangle, the adjacent sides of which are the run and rise of the valley rafter. This rafter is also the hypotenuse of a right-angled triangle with adjacent sides proportional to the length and the run of the common rafter as shown in *Fig.* 186. The methods of finding the length, cuts, and shortenings are identical with those explained for the hip rafter.

Valley jack rafters

The methods used to find the lengths, cuts, and diminish of jack rafters are also employed for valley jack rafters.

Shortening valley jack rafters

Shortenings, as shown in *Figs.* 187 and 188, must be allowed according to the position of the rafters.

In *Fig.* 187 the plan is shown of a jack rafter framed between hip and valley rafters. In this case the rafter must be shortened by the distance AB at both the top and the bottom ends of the rafter. The methods of shortening are identical with those explained for jack rafters.

Fig. 188 shows the shortenings for valley jack rafters between a ridge and a valley.

Geometrical method No. 2 (Short method)

This geometrical method is one that is frequently used on a job. Instead of drawing plan, sections or elevations as previously, only the right-angled triangle containing the lengths and cuts is drawn. It is simply a case of knowing which triangle is to be drawn for a particular cut or length and then drawing the triangle to scale. The scale length of rafters may thus be measured and the angles or cuts set on a bevel and then applied to the timber being marked. A carpenter usually sets out these triangles on a well-dressed board or a piece of plywood,

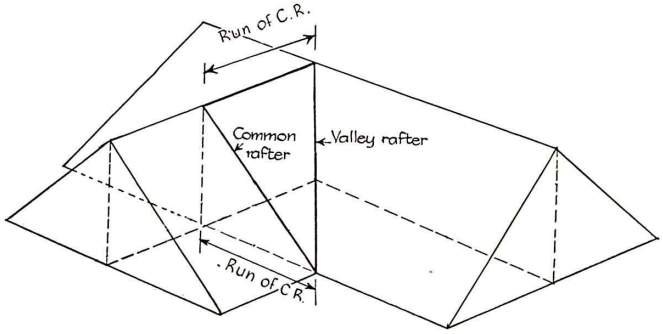


Fig. 186

Outline of roof, position of valley rafter

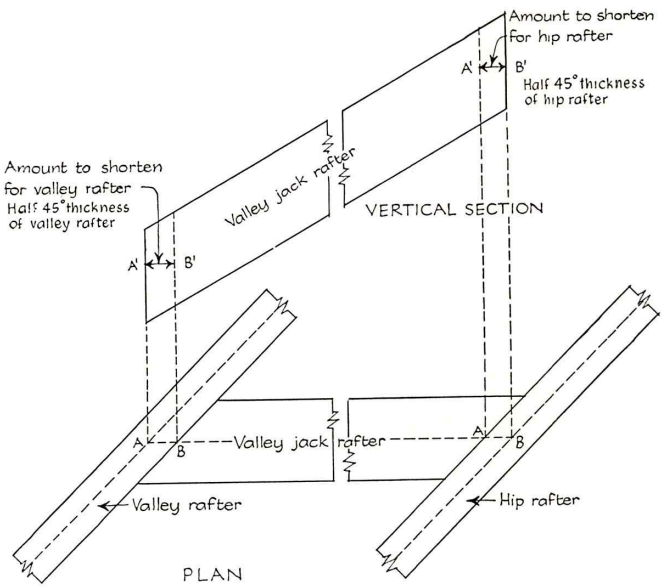


Fig. 187

Part plan and section of hip-valley jack rafter, showing shortening hip-valley jack rafter

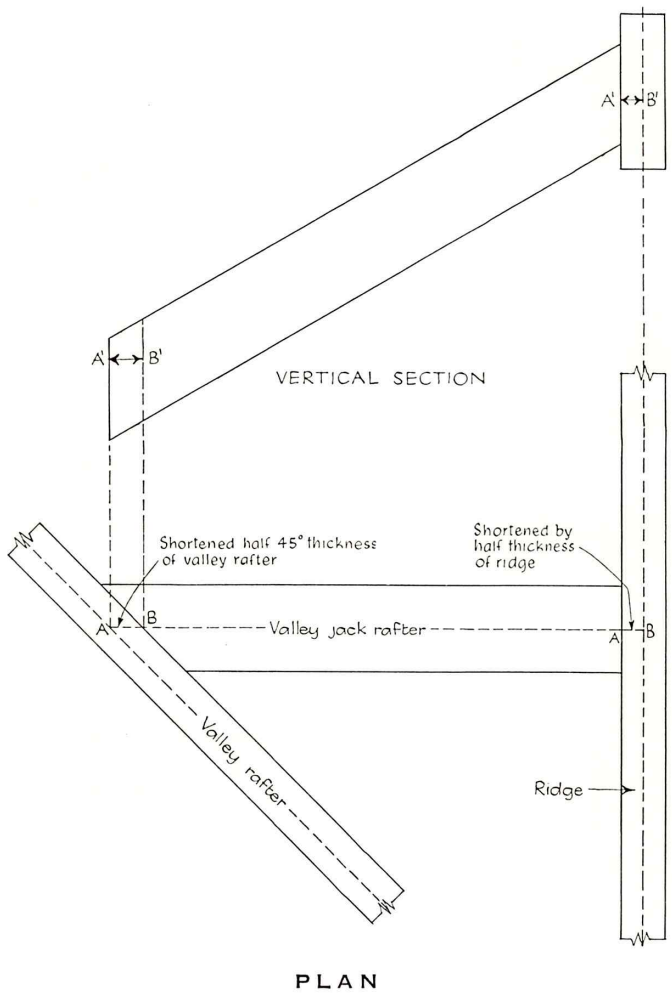


Fig. 188

Part plan and section of valley jack rafter, showing shortening valley jack rafter

the drawing being made to as large a scale as possible. A suitable scale would be 3 in. = 1 ft. The larger the drawing the more accurate will be the results.

Setting out right-angled triangles for a roof

A description will be given of the setting out of the various right-angled triangles that are drawn when setting out the roof shown as a plan in *Fig.* 189. The pitch of the roof is ⅓.

Common rafter

Common rafter 1

The cuts and length of a common rafter are contained in a right-angled triangle whose adjacent sides are proportional to the rise and run of the common rafter. See geometrical method No. 1, page 116.

As the pitch of the roof is ⅓, i.e., $\frac{\text{rise}}{\text{span}}$, and the span is 18 ft. at the left-hand end of the roof, the rise of the rafter is 6 ft. The run of the rafter is 9 ft. Using a suitable scale, draw a horizontal line AB (*Fig.* 190) to represent the run of the common rafter and the line AC perpendicular to AB to represent the rise of the rafter. Join BC, which represents the scale length of the common rafter. The line CB is produced to D and then BD represents the scale length of the overhanging part of the rafter.

Common rafter 3

The span at the particular end of the roof where this rafter lies is 12 ft., and so the run of the rafter is 6 ft. Therefore, as shown in *Fig.* 190, from B make BE equal to 6 ft. and draw from E a perpendicular cutting CB at F. The length of the line FB is the scale length of this common rafter.

The lengths of any number of common rafters of different runs may be found by this method.

The plumb and seat cuts as shown are the same for all common rafters in the roof.

Hip rafters

Hip rafter 2

The triangle containing the length of the hip rafter and the hip rafter overhang is drawn before the triangle containing the plumb and seat cuts of the hip.

The length of any hip rafter may be represented as the hypotenuse of a right-angled triangle whose adjacent sides are proportional to the run and length of the corresponding common rafter. As in *Fig.* 190 measure the run AB and length CB of the common rafter and draw the right-angled triangle shown in *Fig.* 191. The line GB is produced to cut the line of the overhang at H. The line GB represents the length of the hip and BH the length of the hip rafter overhang. The right-angled triangle (see geometrical method No. 1, page 116) having

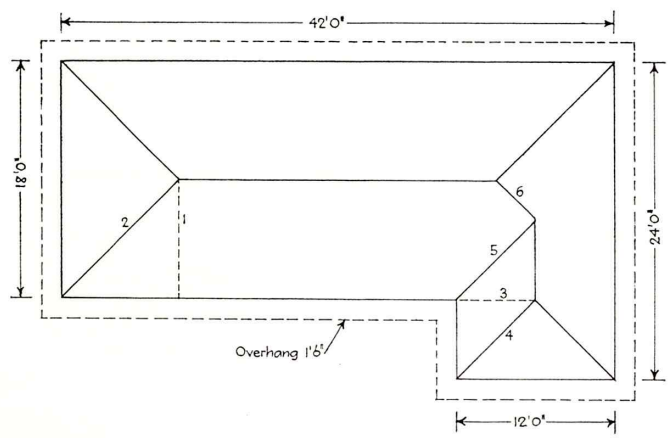


Fig. 189

Plan of hip roof

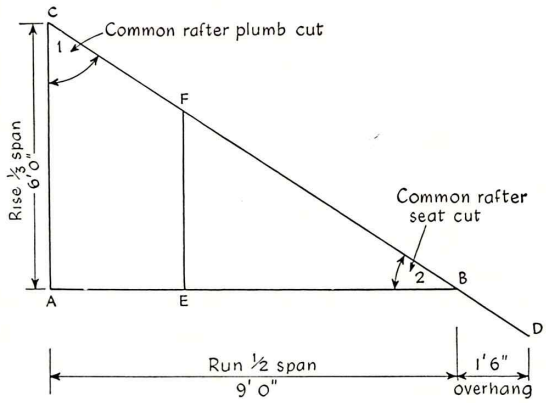


Fig. 190

Lengths and cuts of common rafter

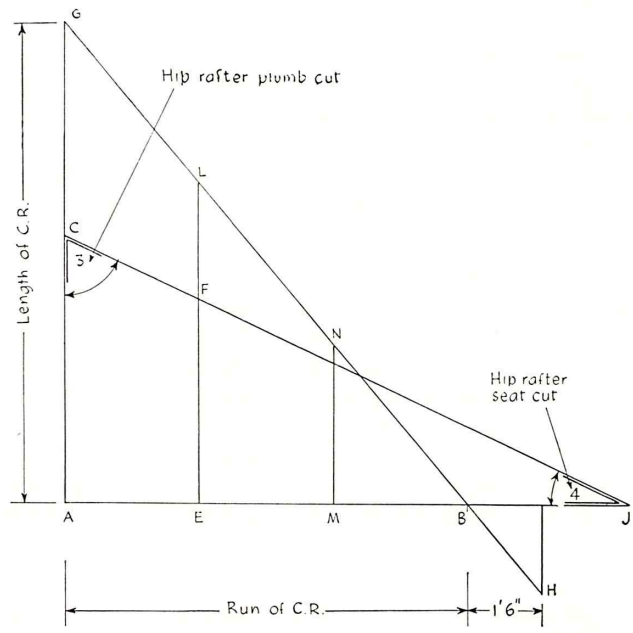


Fig. 191

Length and cuts of hip rafter

adjacent sides proportional to the rise and run of the hip rafter is now drawn and the hip rafter cuts obtained from it.

A hip rafter always has the same amount of rise as the common rafter; so mark AC, the rise of the common rafter, on AG. With C as centre and radius equal to the length of the hip rafter GB (excluding amount of overhang) strike an arc to cut AB produced at J.

The angle No. 3 is the hip rafter plumb cut and the angle No. 4 is the hip rafter seat cut. These cuts apply to all hip rafters.

Hip rafter 4

The run of the corresponding common rafter is 6 ft.; therefore, as shown in *Fig.* 191, on the base line, make BE equal to 6 ft. Project the point E up to cut GB in L. The line LB is the length of hip rafter. The amount of overhang is the same as for other hip rafters.

Valley rafter 5

The length of this rafter is identical to hip rafter 4.

Hip rafter 6

The run of the corresponding common rafter is 3 ft., which is the difference between the runs of the two common rafters in the roof. See *Fig.* 192. The length of this short hip rafter is found by making BM on the base line AB in *Fig.* 191 represent 3 ft. and drawing a perpendicular to cut GB in N. The line NB represents the length of hip rafter 6.

Hip and valley edge cuts (*Fig.* 193)

The edge cut for a hip or valley rafter is the angle opposite the run in a right-angled triangle the adjacent sides of which are proportional to the run and length of the hip (see geometrical method No. 1, page 117). For the sake of convenience the drawing of this triangle may be reduced in scale (*Fig.* 193). The hip rafter triangle AJC (*Fig.* 191) is drawn and OR made perpendicular to AJ from any convenient point O. Then OJ and RJ represent the length and run of the hip rafter to a reduced scale. Draw JP perpendicular to JO and equal in length to JR. Join OP. The angle No. 5 is the hip and valley edge cut.

Hip backing angle

The hip backing angle is contained in a right-angled triangle whose adjacent sides are proportional to the length and rise of the hip, the angle opposite the length of the hip being the hip backing angle. (See geometrical method No. 1, page 118.)

As shown in *Fig.* 193, draw GW perpendicular to GB, make GW equal to the rise of the particular hip rafter, i.e., AC = 6 ft., and join WB. The angle No. 6 is the hip backing angle.

Jack rafters

A right-angled triangle with adjacent sides proportional to the length and run of the common rafter will give the length of each jack rafter, the edge cut for jacks,

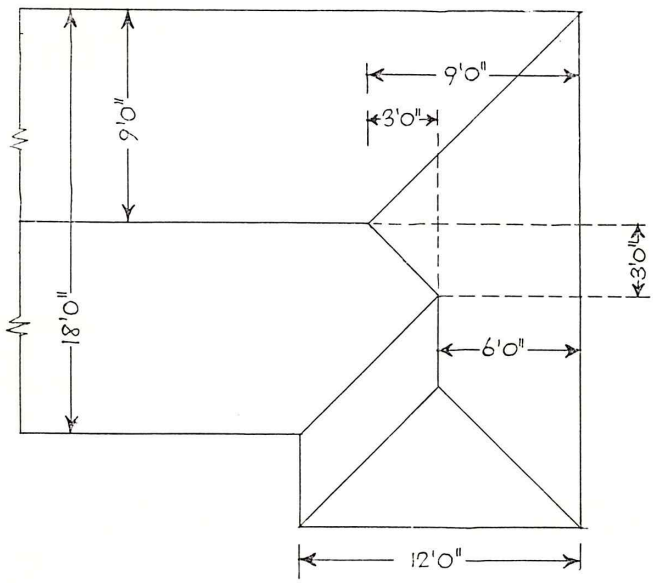


Fig. 192

Part plan of roof showing run of "short" hip rafter

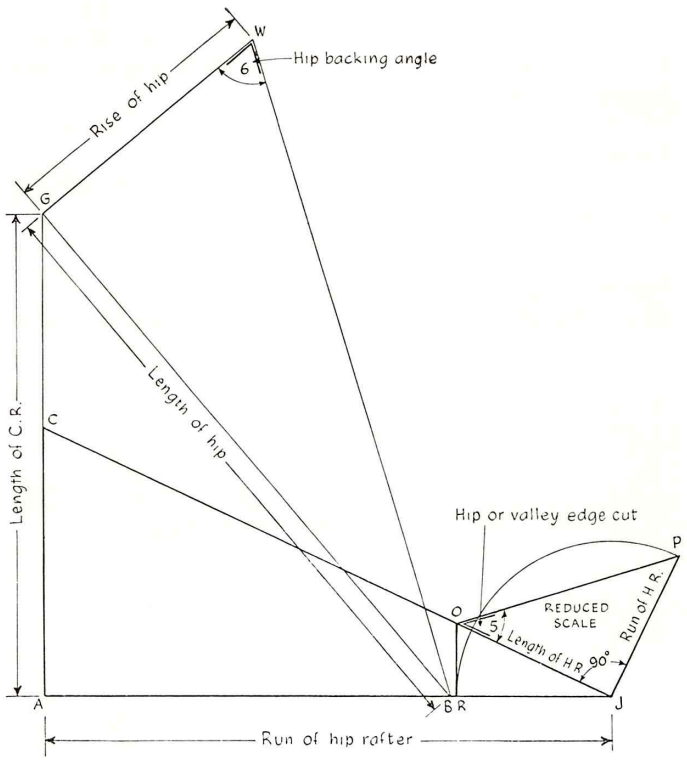


Fig. 193

Hip and valley edge cuts and also backing angle of hip rafter

and the mitre edge cut for purlins. (See geometrical method No. 1, page 119.)

In *Fig.* 194 the right-angled triangle ABG has adjacent sides representing the run and length of the common rafter with the hypotenuse representing the length of the hip rafter.

The spacings of the jack rafters are set out on the base line AB as shown. From each mark, perpendiculars are drawn to cut the hypotenuse at the various points marked on the diagram. So that the overhang is included in the length of each jack rafter, the various points on the base line AB are each projected downwards to the line UH. This construction for the amount of overhang of a rafter was shown previously. The scale length of each jack rafter is represented on the diagram and may be measured. T^5–S^5 is the length of the longest jack rafter, exclusive of the amount of overhang, and lengths of other jack rafters may be measured accordingly. The angle No. 7 is the jack rafter edge cut.

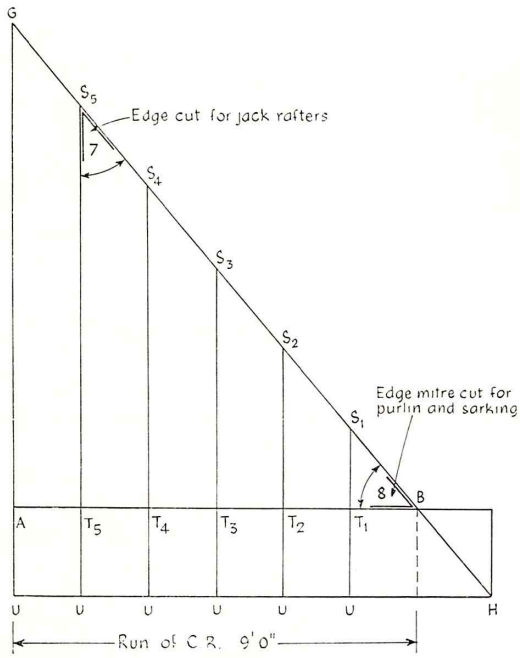


Fig. 194

Length and cuts of jack rafters

Purlin cuts

Purlin edge cut

The purlin edge cut is contained in the right-angled triangle whose adjacent sides are proportional to the run and length of the common rafter. (See geometrical method No. 1, page 119.)

As shown in *Fig.* 194 the angle No. 8 is the top or edge mitre cut for the purlin. This cut is also the mitre cut for the sarking.

Purlin side cut (face cut)

The purlin side cut is contained in the right-angled triangle whose adjacent sides are proportional to the rise and length of the common rafter. (See geometrical method No. 1, page 119.)

To find the cut for the side of a purlin draw a triangle, *Fig.* 195, the adjacent sides of which represent the rise and length of the common rafter. Join GM. The angle No. 9 is the side cut for the purlin.

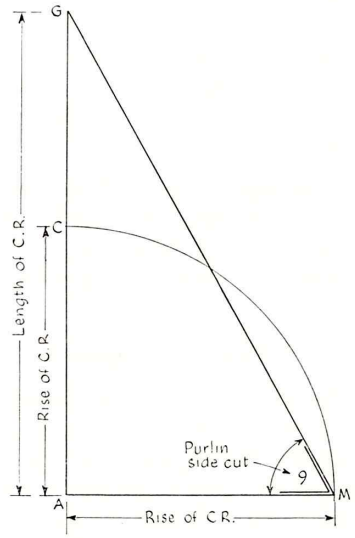


Fig. 195

Purlin side cut

Summary

The work in this section has been set out by means of several drawings, but in actual practice one drawing only, as shown in *Fig.* 196, needs to be made.

Table 7 shows all the scale lengths and cuts of rafters which have been set out in *Fig.* 196.

Table 7

Lengths of rafters (*Fig.* 196)
Common rafter No. 1–line CB.
Common rafter No. 3–line FB.
Overhang of common rafters–line BD.
Hip rafter No. 2–line GB and CJ.
Hip rafter No. 4–line LB.
Hip rafter No. 6–line NB.
Hip rafter overhang–line BH.
Valley rafter No. 5, same as hip rafter No. 4–LB.

Lengths of jack rafters: T_5S_5
T_4S_4
T_3S_3
T_2S_2
T_1S_1

The overhang of the jack rafters is the same as that of the common rafters.

Cuts

Common and jack rafter plumb cut, angle 1.
Common and jack rafter seat cut, angle 2.
Jack rafter edge cut, angle 7.
Hip and valley plumb cut, angle 3.
Hip and valley seat cut, angle 4.
Hip and valley edge cut, angle 5.
Hip backing angle, angle 6.
Purlin mitre edge cut, angle 8.
Purlin mitre side cut, angle 9.

Note: If a purlin is fixed on its flat, the side and edge cuts would have to be reversed.

In this section the lengths of all rafters have been assumed to be taken on centre lines. In marking the lengths of rafters, allowances must accordingly be made for the shortening of rafters, as previously explained.

The steel square

The steel or framing square is an invaluable device for roof and stair work. On roof framing it is used to determine quickly the length and cuts of the various members for any roof pitch; and once a few simple rules are known the reader will find it easy to use. The square is used with a fence to make right-angled triangles of various sizes.

Description of square

The steel square is made with its two arms, known as the body and the tongue, at an angle of 90° to each other (*Fig.* 197).

The body of the square is usually 24 in. long and 2 in. wide and the tongue is from 16 in. to 18 in. long and $1\frac{1}{2}$ in. wide, although these dimensions may vary with different makes of squares. Most squares have rafter and other tables stamped on both sides of the square but these tables may be disregarded in the meantime while we consider the principles involved in roof framing. When these principles are thoroughly understood the use of rafter tables may be quickly learned.

Heel

The heel of a square is the point at which the body and the tongue meet on the outside edges of the square.

Face

The face is the side on which the manufacturer's name is stamped.

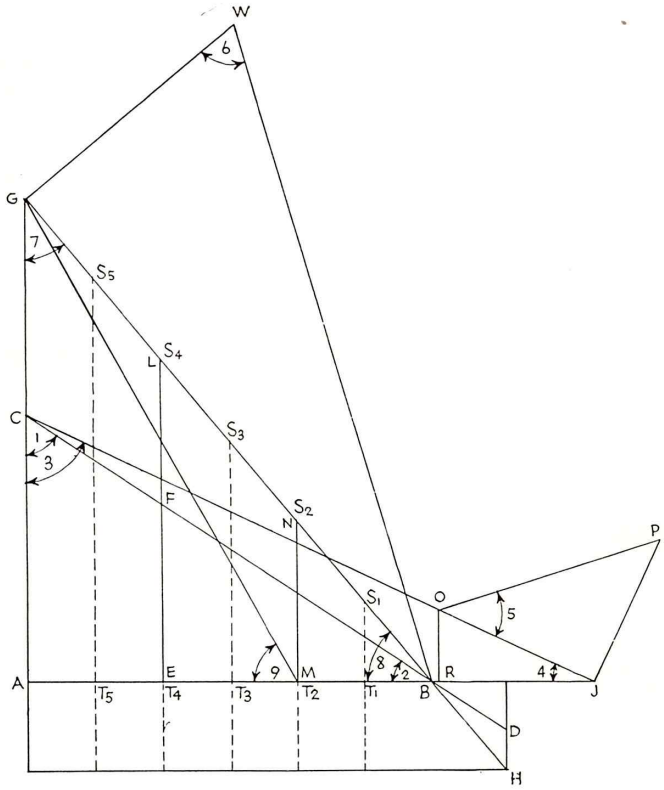


Fig. 196
Length and cuts of rafters for a hip roof

Back

The back of a square is the reverse side.

Graduations

Both sides of a square are graduated into inches and fractions of an inch as follows:
Face of body–outside edge–inches and sixteenths.
Face of body–inside edge–inches and eighths.
Face of tongue–outside edge–inches and sixteenths.
Face of tongue–inside edge–inches and eighths.
Back of body–outside edge–inches and twelfths.
Back of body–inside edge–inches and sixteenths.
Back of tongue–outside edge–inches and twelfths.
Back of tongue–inside edge–inches and tenths.

The scale most frequently used is 1 in. to 1 ft. ($\frac{1}{12}$ full size) in which case $\frac{1}{12}$ in. represents 1 in.

Fence

A right-angled triangle is formed when the arms of a framing square are connected by a fence (*Fig.* 197) which is made of a piece of hardwood or other timber that will not warp. Its dimensions are 1 in. x $1\frac{1}{4}$ in. x 28 in. when used on a square with a 16 in. tongue, and it is 34 in. long with an 18 in. tongue. A slot in the fence allows it to fit over the arms of the square and it is secured in any desired position by two bolts and wing nuts. It forms a movable hypotenuse of a right-angled

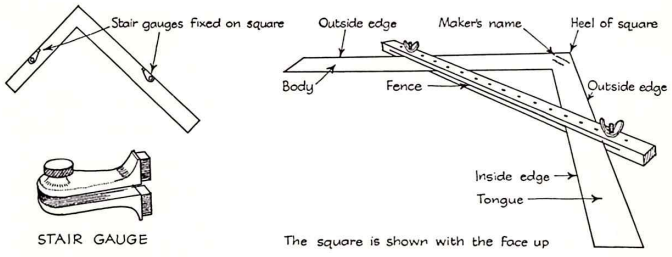


Fig. 197

Steel framing square and fence

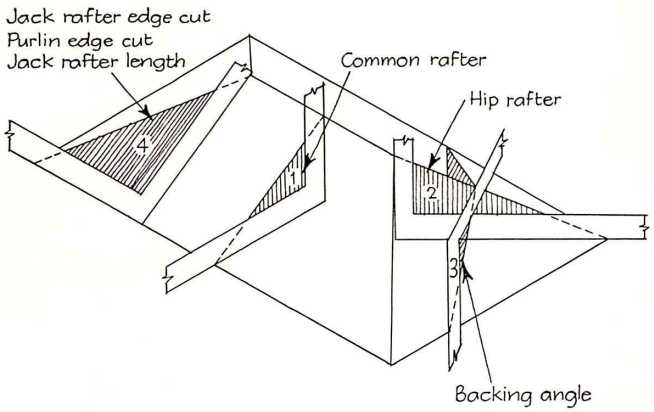


Fig. 198

Positions of framing square in hip roof

triangle. Instead of using a fence, clips known as stair gauges (*Fig.* 197) may be fixed on each arm of a square, and then the edge of the piece of timber being marked forms the hypotenuse of the right-angled triangle. More accurate results may be obtained by using gauges because they do not obscure the markings on the square to the same extent as a fence.

Use of framing square

Fig. 198 is similar to *Fig.* 176 except that framing squares have been placed over the various triangles in the roof. When seeking information about a rafter, the respective lengths of the adjacent sides of the right-angled triangles are applied to the arms of the framing square. The fixing of the fence to these points completes the various triangles.

If the view of the roof shown in *Fig.* 198 is considered as a model roof, built to scale, it will be obvious that the framing square and fence (not shown) in each case represent a right-angled triangle with adjacent sides proportional to the rise, run, or length of a rafter. It will be seen that the square provides a means of lifting these triangles from a roof (or plan) for the purpose of marking out the various rafters.

Methods of using a framing square

The framing square may be used in the following three ways:

(1) Method based on rise and run of rafters to a scale of 1 in. to 1 ft. or $\frac{1}{12}$ scale.

(2) Method based on rise and run of rafters in terms of rise in inches per foot of run.

(3) Rafter tables stamped on square.

This section of the work outlines methods 1 and 2.

First method

Setting out rafters with a framing square

Consider the plan of the roof shown in *Fig.* 199 with a span of 18 ft. and a rise of 6 ft. Rafters are 2 in. thick and spaced at 18 in. centres. As in previous instances, with the exception of those lines which represent the outside edges of wall plates, all lines are centre lines of roof members. For speed and accuracy a fence or gauges must be used with a steel square, but in most of these illustrations, the fence has been purposely omitted so that the markings on each arm of the square may be clearly seen.

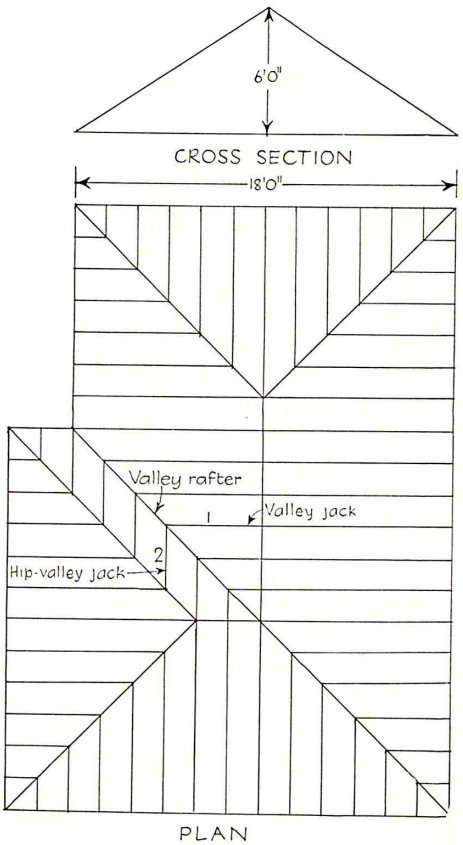


Fig. 199

Plan of hip roof

Common rafters

Length of common rafter

In this case the rise of the roof is 6 ft. and the run of the common rafter is 9 ft. As the square is graduated in inches and twelfths of an inch, the adjacent sides of the common rafter triangle are represented on the framing square by 9 in. run on the body of the square and 6 in. rise on the tongue. The hypotenuse of the triangle is represented by the slope of the roof; so the distance from 6 in. on the tongue to 9 in. on the body represents the scale length of the common rafter. *Fig.* 200 shows these dimensions on a framing square over a cross section of the roof, the square being shown of such a size that the markings may be seen. (Wherever possible it is advisable to represent the run of a rafter on the body of a square and the rise on the tongue.)

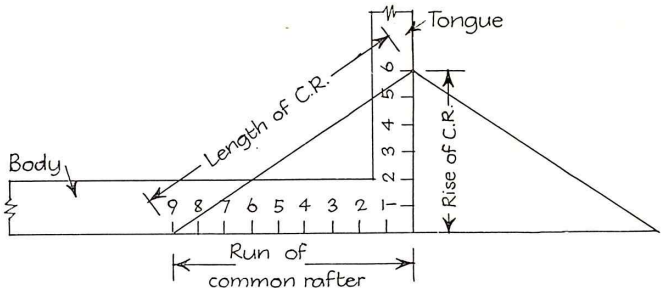


Fig. 200

Scale length of common rafter

Setting out common rafter

The common rafter is marked out by a process of making repeated applications of a square to the side of a rafter. On the square a fence is fixed connecting the points of the run and the rise of the common rafter.

Commencing at the top end of the rafter, draw a plumb mark alongside the tongue of the square and then one alongside the body (*Fig.* 201). This is the first application of the square. Now slide the square along the rafter until the tongue of the square coincides with the outside extremity of the line previously made alongside the body of the square, and mark another line alongside the body of the square. This is the second application of the square. Repeat these applications of the square eleven more times. As shown in *Fig.* 202, it will be seen that when the square has been moved from the first to the second position it has shifted 9 in. in the horizontal and 6 in. in a vertical direction, and over twelve applications has moved 9 ft. horizontally and 6 ft. vertically, which distances correspond to the run and rise of the common rafter. When one is experienced in using the square, a more accurate result is obtained by making six applications of the square of 18in. x 12 in. instead of twelve applications of 9 in. x 6 in. During the process of repeatedly applying the square, marking errors can accumulate with each successive move, so that the result could be far from accurate. It will be obvious that very great care must be taken in marking out and that six applications of the square are likely to produce more accurate results than twelve.

The length of the rafter is that distance measured along its top edge from the first to the last mark made at the lower end. A method of checking this length is to measure across the square from 6 in. on the tongue to 9 in. on the body (*Fig.* 203), which will give the scale length of the rafter. As a carpenter's rule is not always graduated in twelfths of an inch, this measurement could be made with the edge of another framing square so graduated.

Odd inches of run and rise

When the run or the rise are not expressed in whole numbers but in feet and inches, these measurements are

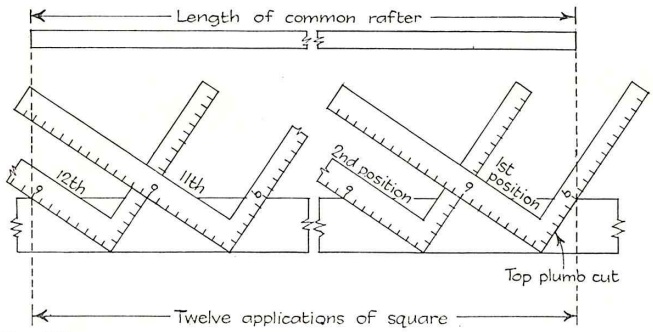


Fig. 201

First and last position of square

applied on the square in inches and parts of an inch. For example, a rise of 6 ft. 4 in. would be represented on the square by $6\frac{4}{12}$ in., and a run of 10 ft. 9 in. by $10\frac{9}{12}$ in. The twelve applications of the square are made in the manner described.

Summary

The length of a rafter may be determined by either of the following methods:

(1) Repeated applications of the square.

(2) Measuring the scale distance across the square.

Overhang of common rafter

The overhang of the common rafter is set out with the same settings on the square as those used for the common rafters, the number of applications depending upon the run of the overhang (width of eaves soffit) (*Fig.* 204). If the common rafter has been set out with 9 in. on the body of the square, two applications would be required for an overhang run of 18 in. (*Fig.* 205). When inches and a fractional part of an inch, such as $10\frac{3}{4}$ in., are set on the body of the square, one application of the square would represent a run of $10\frac{3}{4}$ in. and consequently, as this is short of 18 in. by $7\frac{1}{4}$ in., a second application is necessary and a plumb mark is made through the $7\frac{1}{4}$ in. graduation mark. In *Fig.* 199 no rafter overhang is shown.

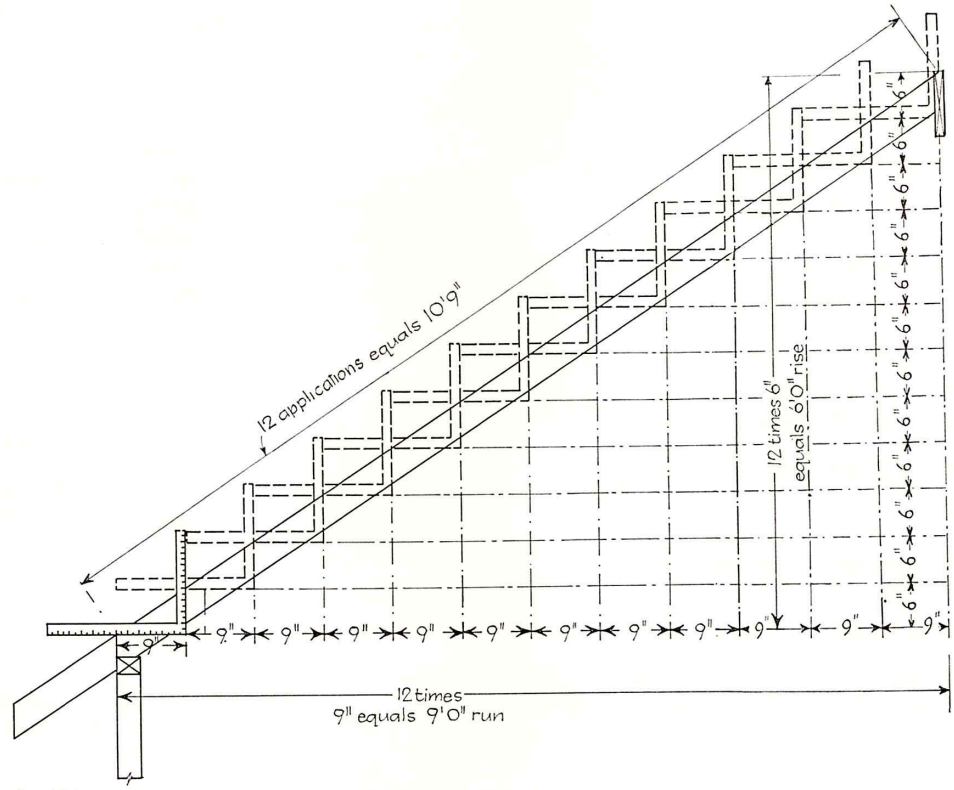


Fig. 202

Setting out common rafter with a steel square

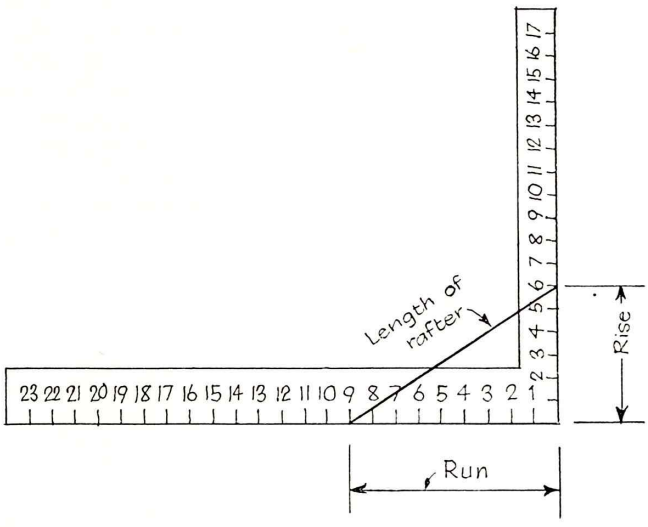


Fig. 203

Scale length of common rafter

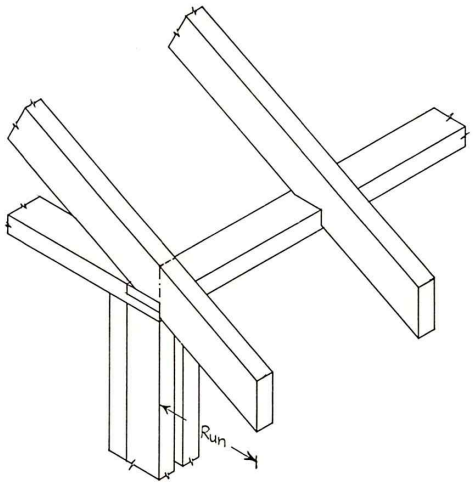


Fig. 204

Overhang of common rafter

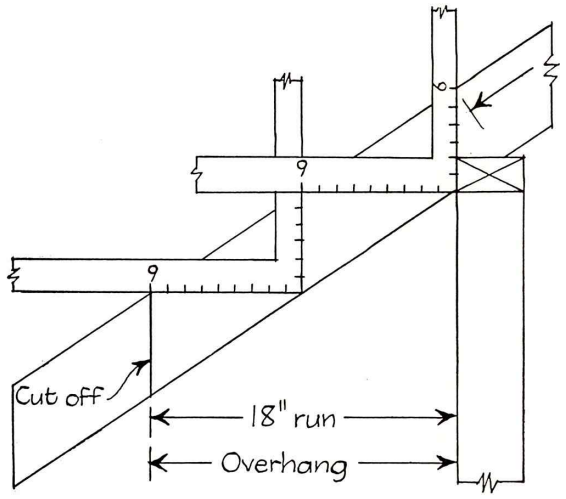


Fig. 205

Setting out overhang of common rafter

Shortening of common rafter

A common rafter is shortened by one-half the thickness of the ridge. This process may be carried out immediately after the first plumb mark has been made, or left until the rafter has been completely set out. The square is placed in the position, as shown in *Fig.* 206, a distance of half the thickness of the ridge away from the plumb cut. Shortening distances are always measured horizontally or square off the plumb cut.

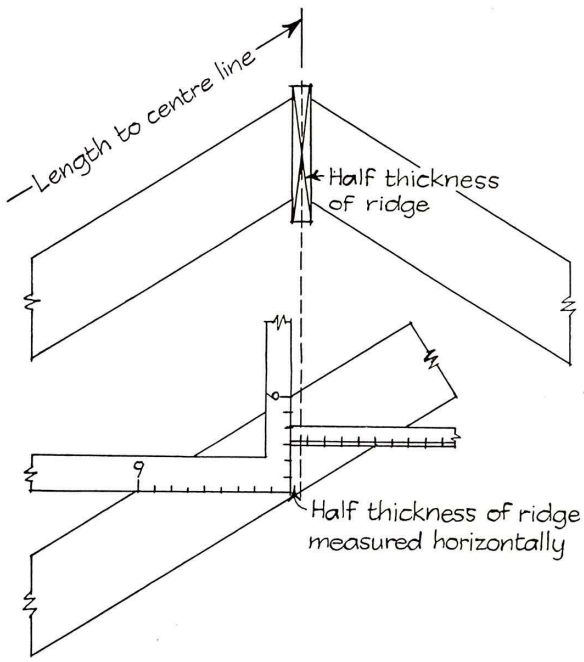


Fig. 206

Shortening common rafter

Seat cut of common rafter

The seat cut of a common rafter is set out as shown in *Fig.* 207. The lower end of the rafter is first divided into three parts and from the intersection of the lower-third line and the plumb mark the seat cut is marked by moving the square to the point of intersection and then marking a line alongside the body of the square.

A rafter is often divided into four parts, instead of three, so that a smaller birdsmouth is formed and consequently a lesser amount is removed from the rafter.

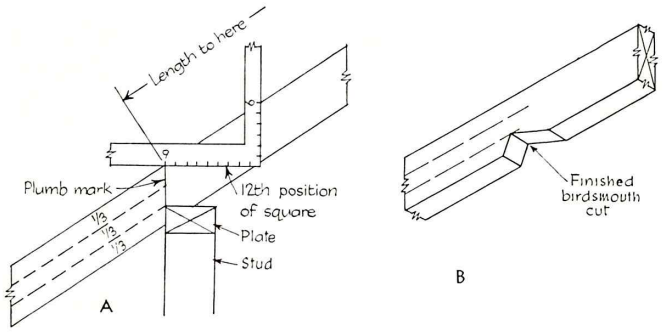


Fig. 207

Setting out seat cut of common rafter

(A) *Position of seat cut* (B) *Finished birdsmouth cut*

Hip rafters

Length of hip rafter

The length of the hip rafter is determined from the right-angled triangle whose adjacent sides are proportional to the run and the rise of the hip. (See geometrical method No. 1, page 116.) The rise of the hip rafter is the same as that of the common rafter (6 ft.) and therefore is known, but the run must be determined. As the run of a hip rafter is the diagonal of a square whose sides are equal to the run of the common rafter (*Fig.* 208), fix the run of the common rafter on each arm of the framing square and then make twelve applications of the square. The distance is measured from the first to the last mark made, and this is the run of the hip rafter (12 ft. 9 in.). To check this result, the scale distance may be measured across the square as shown in *Fig.* 209. As the rise of the hip rafter is always the same as that of the common rafter (6 ft.), to find the length of the hip rafter the rise is represented on the tongue as 6 in. and

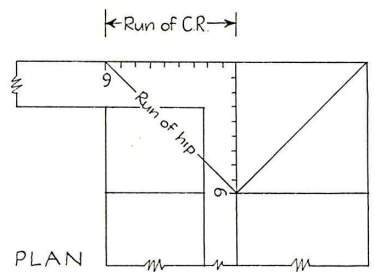


Fig. 208

Steel square on plan of roof

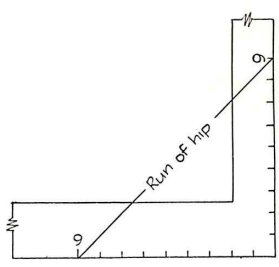


Fig. 209

Scale measurements on square

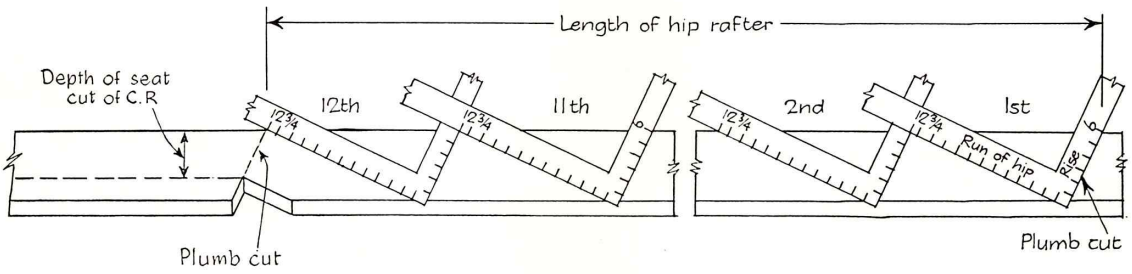


Fig. 210

Setting out length and cuts of hip rafter

the run as 12¾ in. on the body of the square, and then *twelve* applications of the square are made in the manner already described for setting out the common rafter. The length is measured along the top edge of the piece of timber (*Fig.* 210), and a check on the result is found by measuring across the square as shown in *Fig.* 211. The seat cut is set out as shown in *Fig.* 210.

Alternative method of finding length of hip rafter

Imagine a right-angled triangle in a roof with adjacent sides equal to the length and the run of the common rafter, the run being set out along the wall plate from the corner of the building. The hip rafter is the hypotenuse of this triangle (*Fig.* 212). As the length and run of the common rafter are known, it is an easy matter to represent these dimensions on a steel square and measure the distance across the square to find the scale length of the hip rafter. This method could be used to check the accuracy of the other methods described.

Hip rafter overhang

Fig. 213 shows that the run of the hip rafter overhang is really the diagonal of a square of which the sides are equal to the run of the common rafter overhang. It is necessary to determine this distance and this is done by representing the run of the common rafter overhang on each arm of the framing square and measuring the diagonal distance between the points. In setting out the hip rafter overhang, the same settings that were used to set out the hip rafter are employed and every application of the square gives, for example, a run of 12¾ in. (*Fig.* 214). If, however, the run of the overhang is 21 in., on the second application of the square, a plumb line is made through the 8¼ in. graduation mark as was done when marking the fractional part of the common rafter overhang.

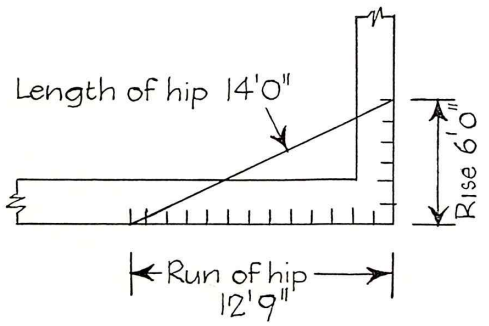


Fig. 211

Scale length of hip rafter

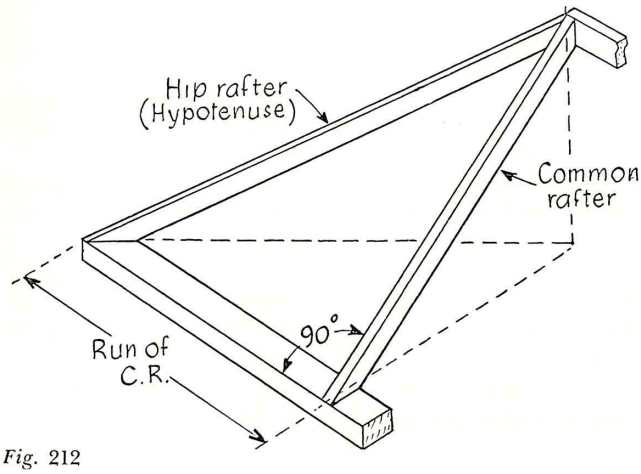


Fig. 212

Right-angled triangle with adjacent sides of run and length of common rafter

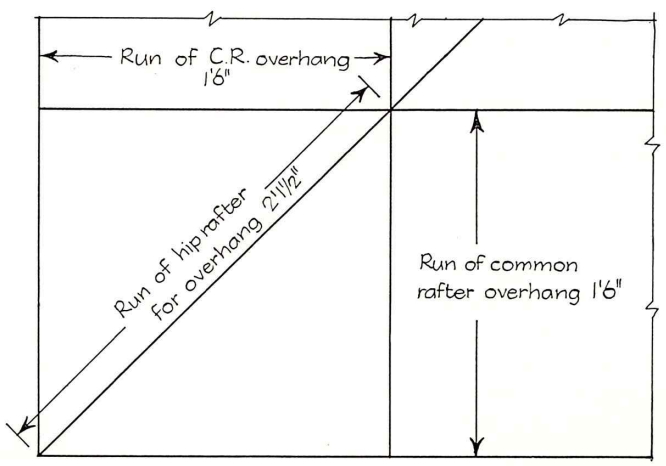


Fig. 213

Plan of hip rafter overhang

Shortening of hip rafter

In shortening the hip rafter allowance must be made for the members against which this rafter is framed. Various arrangements of the members at the apex of the roof are possible, but the most common arrangement is that shown on page 117. From the plumb mark at the top end of the rafter, a shortening is made of a distance equal to half of the 45° thickness of the common rafter and this is measured, square off the plumb mark. The framing square is used to mark the top plumb cut of the rafter (*Fig.* 215).

Finding diagonal thickness with the framing square

When a line is marked across the edge of a rafter at an angle of 45° it is said that the total length of this line is the diagonal or mitre thickness of the rafter. In practice the length of this line is found by measuring across the square from the same number on each arm of the square (*Fig.* 216). When a rafter must be shortened by half the 45° thickness, half the above distance is deducted.

Edge cut of hip rafter

The adjacent sides of the right-angled triangle in this case are the run and length of the hip rafter. (See geometrical method No. 1, page 117.) As shown in *Fig.* 217, the edge cut of the hip rafter is marked with the scale length of the hip rafter represented on the tongue and the run of the hip on the body of the square.

Fig. 218 shows how the edge cuts are marked. The rafter must first be shortened before the edge cut is marked, and then the plumb line EF is squared on to the edge of the material to the point C on the centre line. From this point the edge cuts are marked with the framing square applied from both sides of the rafter.

Seat cut of hip rafter

The seat cut for the hip rafter is formed with the fence on the square set to the rise and run of the hip rafter, the mark for the cut being made along the body of the square, as shown in *Fig.* 219A.

Note in *Fig.* 219B that the depth of the seat cut from the backing line of the hip rafter is the same as that for the seat cut of the common rafter. The plumb cut of the birdsmouth of a hip rafter is rarely made to fit the corner of the building because it is an awkward cut to make and carpenters find it easier either to cut the corner off the wall plates or to make the plumb cut slightly outside the corner of the wall plates. *Fig.* 220 shows the positions of both cuts. When the plumb cut of the birdsmouth is made outside the wall plates the edge cut coincides with the line EF. When the corners of the plates are to be sawn across, the edge cut coincides with line AC, and as the distance BD is equal to one-half the thickness of the hip rafter, the plumb cut of the birdsmouth is moved accordingly a horizontal distance of half the thickness of the rafter.

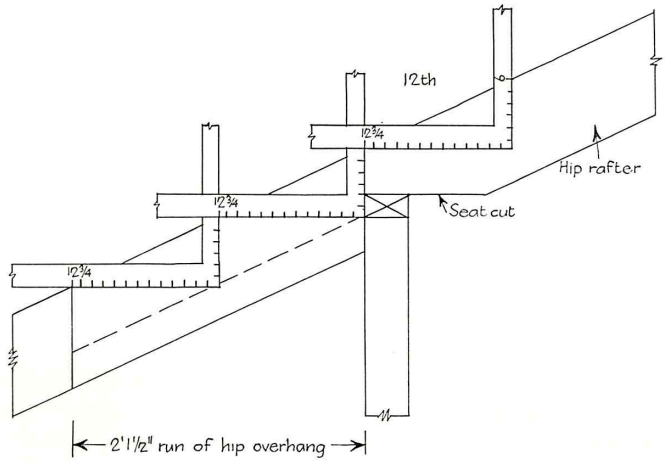


Fig. 214

Setting out of hip rafter overhang

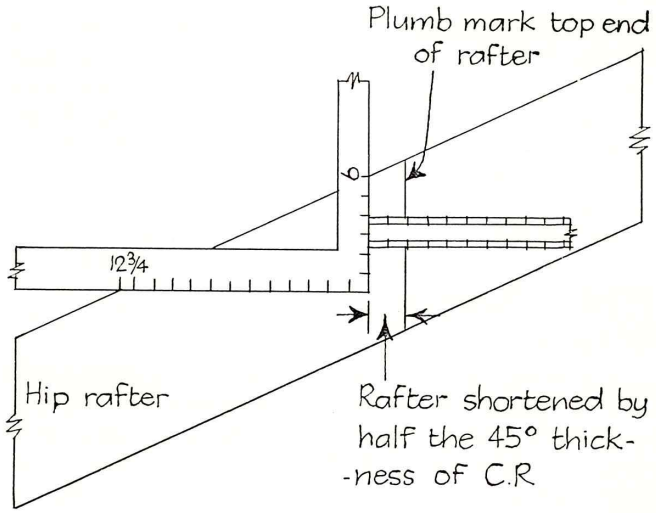


Fig. 215

Shortening of hip rafter

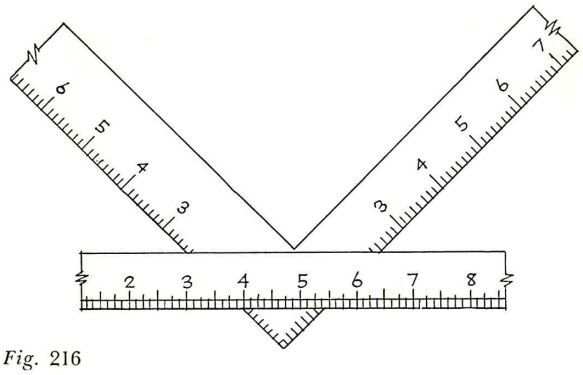


Fig. 216

Finding mitre or diagonal thickness of a rafter

Backing angle of hip rafter

The angle to which the top edge of a hip rafter is bevelled is contained in a right-angled triangle whose adjacent sides are proportional to the length and rise of the hip rafters. (See geometrical method No. 1, page 118.) Each bevel is marked with the square in the positions as shown in *Fig.* 221 with the length of the hip rafter set on the body and the rise on the tongue of the square.

Jack rafters

Edge cut of jack rafters

The edge cut of a jack rafter is contained in the right-angled triangle whose adjacent sides are proportional to the run and the length of the common rafter. (See geometrical method No. 1, page 119.)

Fig. 222 shows the position of an enlarged square on a roof and *Fig.* 223 a development of that part of the roof with the edge cut of the jack rafter shown. The edge cut of the jack rafter is represented on the framing square (*Fig.* 224) by setting the scale length of the common rafter on the tongue and the scale measurement of the run on the body of the square. Mark alongside the tongue of the square.

Diminish of jack rafters

Shown in *Fig.* 225 is a method of finding the diminish of a jack rafter (i.e., the difference in length of two adjacent jack rafters) by means of the framing square. The square is placed on the edge of a piece of scantling with the length of the common rafter represented on the

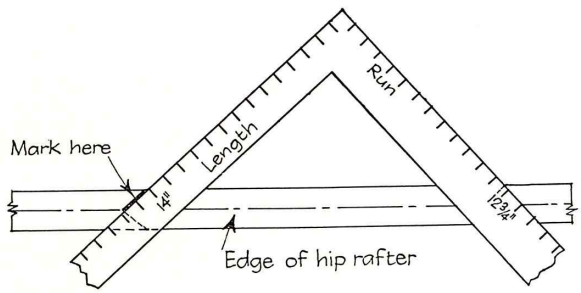


Fig. 217

Edge cut of a hip rafter

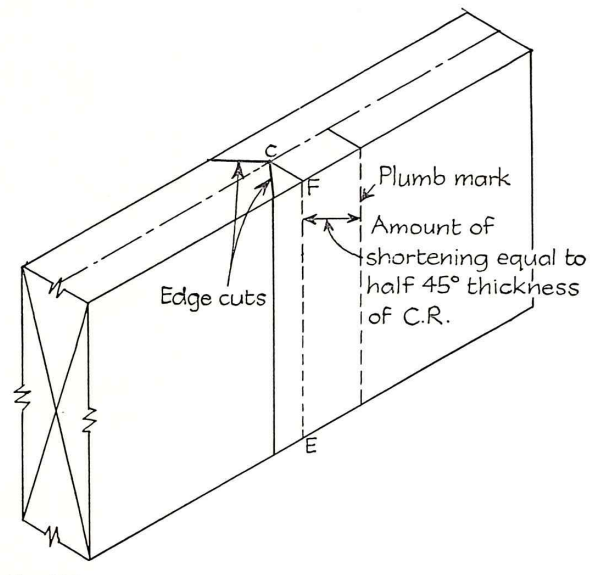


Fig. 218

Marking edge cuts of hip rafter

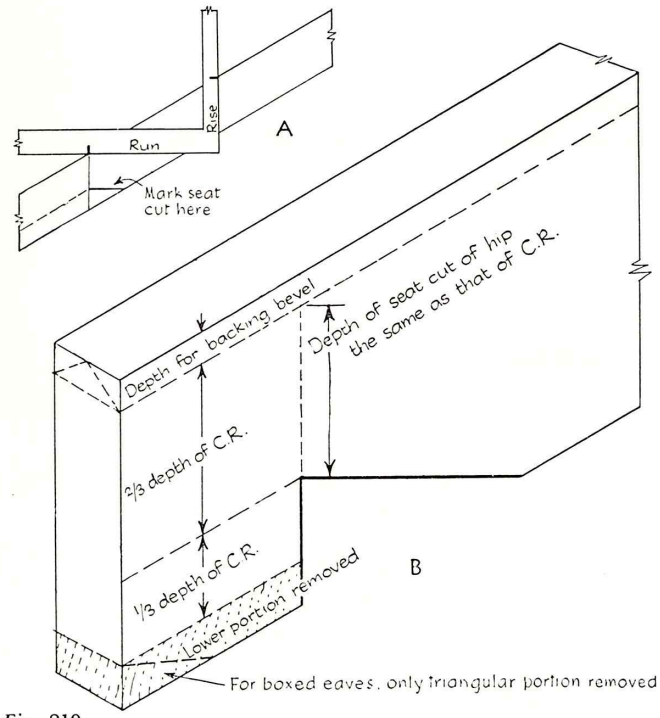


Fig. 219

Seat cut of hip rafter

(A) *Position of seat cut*
(B) *Method of setting out seat cut on hip rafter*

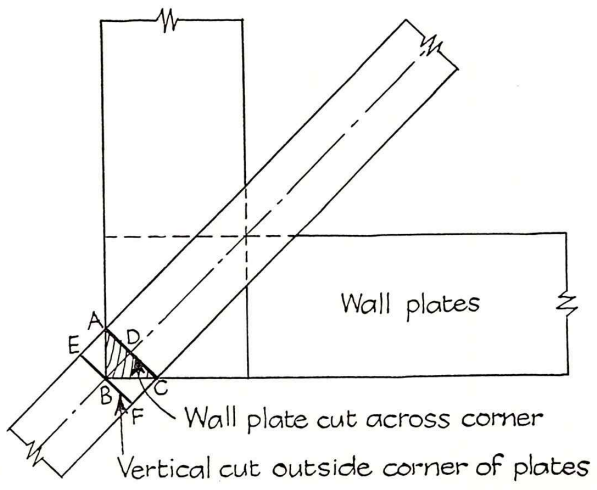


Fig. 220

Position of seat cut of hip rafter on a plan

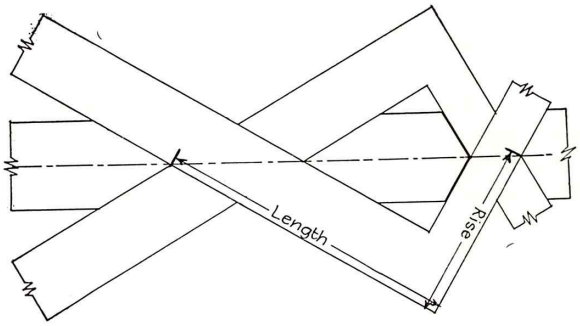


Fig. 221

Marking backing angles of hip rafter on edge of rafter

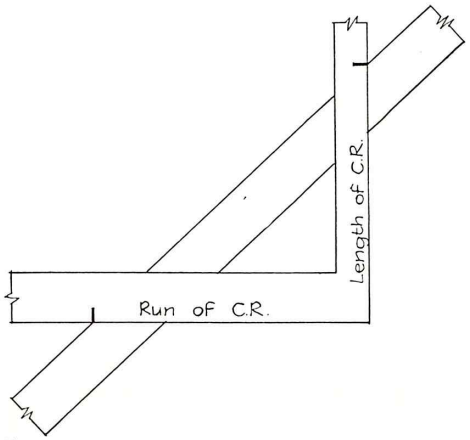


Fig. 224

Measurements on square for jack rafter edge cuts

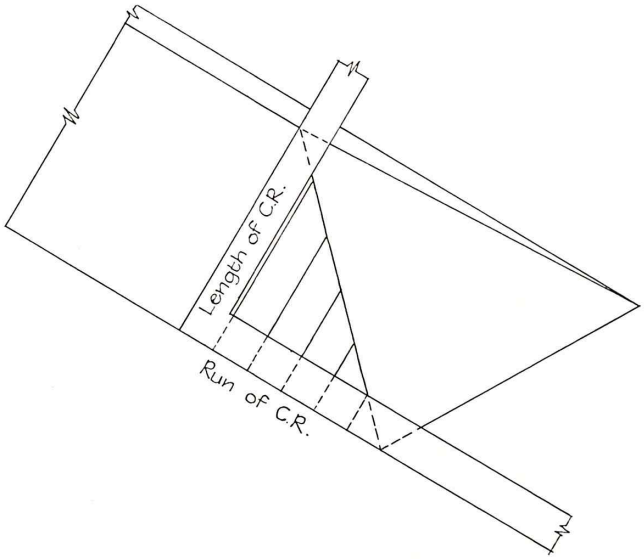


Fig. 222

Edge cut of jack rafters

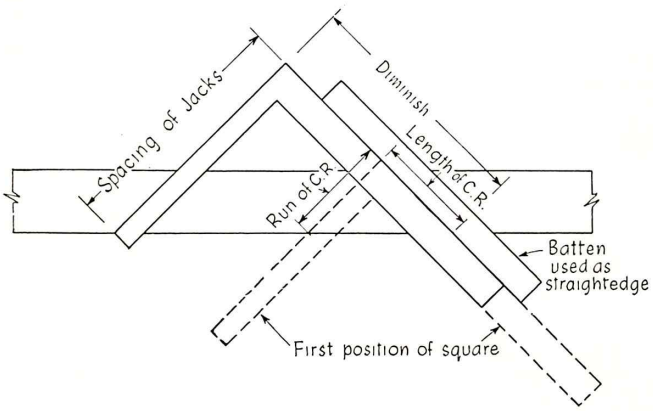


Fig. 225

Diminish of jack rafters

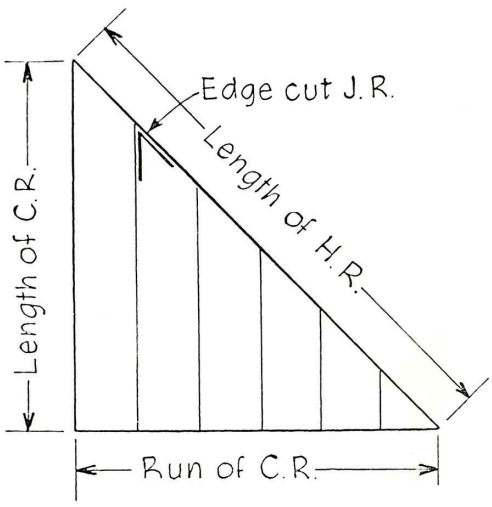


Fig. 223

Lengths and edge cut of jack rafters

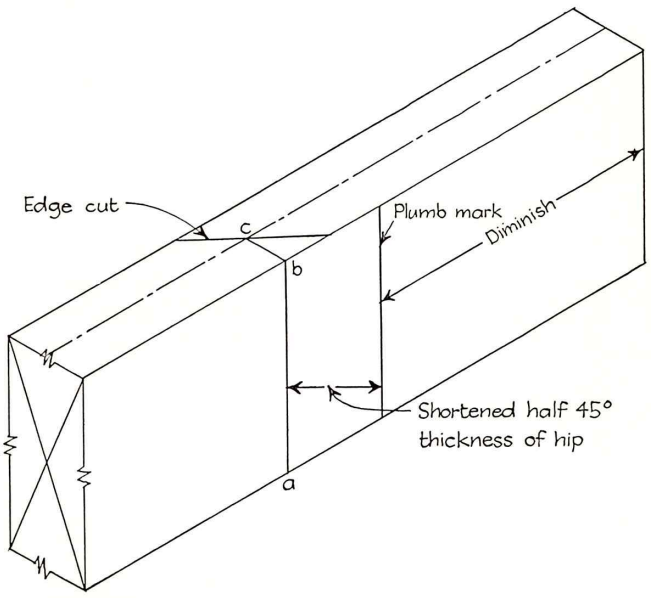


Fig. 226

Cut of longest jack rafter

body of the square and the run of the common rafter on the tongue. A batten is firmly held against the outside edge of the square and then the square is moved until the spacing of the jacks is represented on the tongue of the square as shown. As the tongue of a framing square is not always 18 in. long, a rule must be used for measuring when the rafters are spaced at 18 in. centres. The amount of diminish is measured where shown in the figure.

The above process of sliding the square may conveniently be carried out on a wide board instead of a piece of scantling.

Shortening jack rafters

The jack rafters must be shortened by half the 45° thickness of the hip rafter, measured square off the plumb cut.

Setting out jack rafters on common rafter

Having found the diminish of one jack rafter, all the jack rafters may now be set out on a *full length* (before shortening takes place) common rafter. From the top end of this rafter measure the amount of the diminish and make a plumb cut mark on the side of the rafter (*Fig.* 226). Measure horizontally the distance to be allowed for shortening each jack rafter and mark another plumb line ab, and then square it over on the top edge to the centre line at point c. Through this point the edge cut of the jack rafter (run and length of common rafter) is marked on the top edge of the rafter. A plumb mark is later made on the side of the rafter as a guide when making the cut. This is the cut of the longest jack rafter. The next longest jack rafter is set out by measuring from the long point of the first jack the amount of the diminish, which gives the long corner of the second jack rafter. The remaining jack rafters are each marked on the common rafter, in the manner described, which now serves as a pattern from which the lengths of all jack rafters are taken (*Fig.* 227).

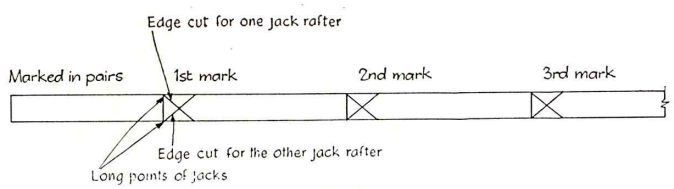


Fig. 227

Length and cuts of jack rafters marked on pattern common rafter

Purlin cuts

Purlin edge cut

The right-angled triangle in this case has adjacent sides proportional to length and run of the common rafter (see geometrical method No. 1, page 119) and is shown in *Fig.* 228. In this case the geometrical construction previously shown has been employed to demonstrate the position of the square.

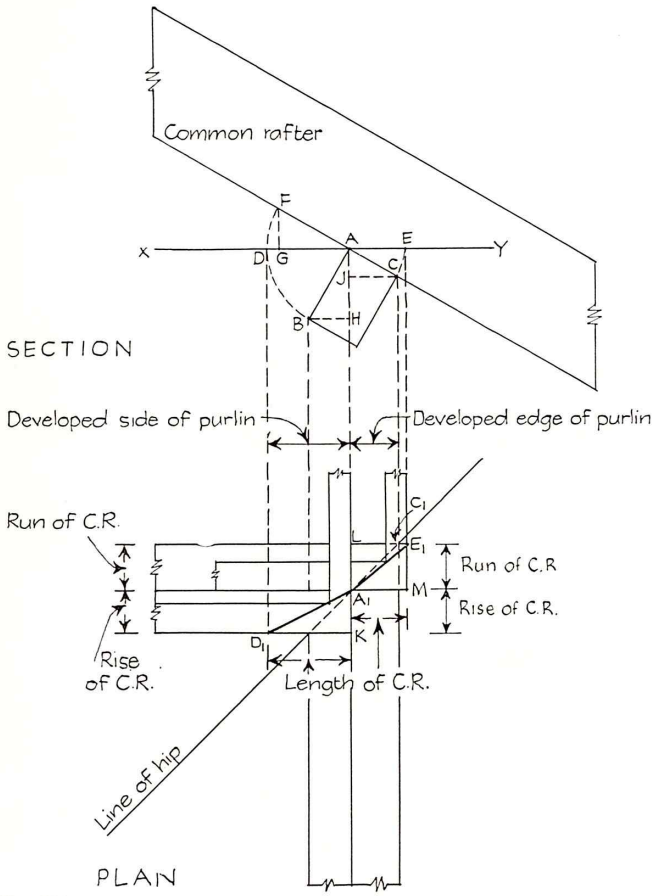


Fig. 228

Side and edge cuts of purlin

On the framing square the length is represented on the tongue and the run on the body of the square. The cut is marked on the run side of the square. This cut also serves for the face cut of tiling battens and sarking boards.

Purlin side cut

The right-angled triangle in this case has adjacent sides proportional to the length and rise of the common rafters (see geometrical method No. 1, page 119). These dimensions are represented on the square as shown in *Fig.* 228. The cut is marked on the rise side of the square.

Valley rafters (*Fig.* 229)

The length and cuts of a valley rafter are almost identical with those of the hip rafter, with the exception of the shape of the vertical cuts of the birdsmouth and the plumb cuts at the extreme lower end of the rafter.

Valley jack rafters

The plan of the roof (*Fig.* 230) shows that two kinds (marked 1 and 2) of valley jack rafters are required for this roof and these are illustrated in *Figs.* 231, 232. It will be seen that one type has a cut at the upper end to

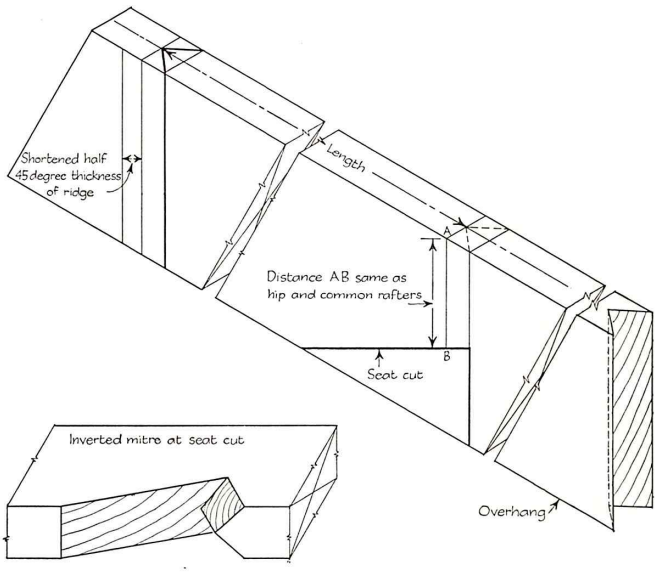


Fig. 229

Cuts of valley rafter

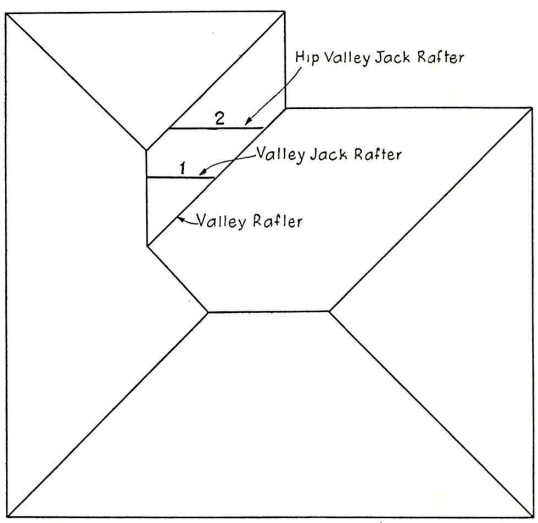


Fig. 230

Types of jack rafters

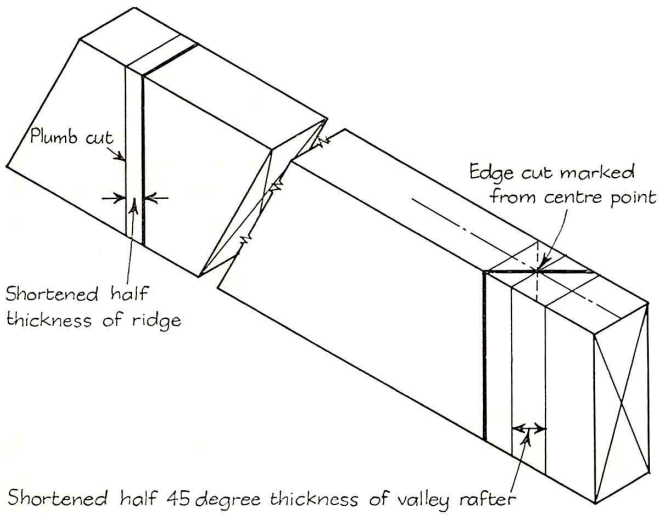

Plumb cut
Edge cut marked from centre point
Shortened half thickness of ridge
Shortened half 45 degree thickness of valley rafter

Fig. 231

Cuts for valley jack rafter

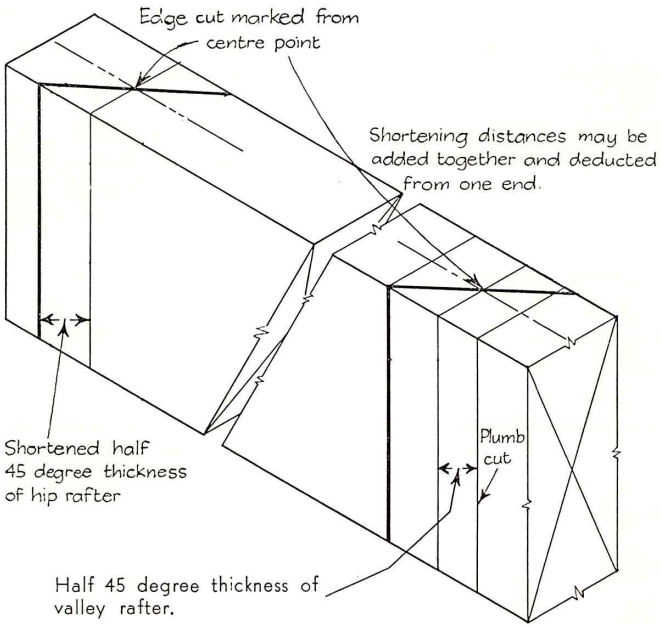

Edge cut marked from centre point
Shortening distances may be added together and deducted from one end.
Shortened half 45 degree thickness of hip rafter
Plumb cut
Half 45 degree thickness of valley rafter.

Fig. 232

Cuts of hip-valley jack rafter

fit against the ridge and at the lower end a cut to suit the valley rafter. The other valley rafter connects the hip and the valley rafters and therefore must have cuts to fit against these members. The edge cut for valley jack rafters is the same as for ordinary jack rafters, but the cut in this case is applied at the lower end of the rafter. In the case of the hip-valley jack rafter the cut is applied at both ends. The diminish of valley jack rafters is the same as for the ordinary jack rafters on the opposite side of the roof. *Figs.* 231 and 232 show the shortenings and general set out for these rafters.

Fig. 233 illustrates the use of a steel square on even-pitch roofs.

Second method

This method uses the same right-angled triangles but differs in that the measurements taken on the square are based on only 1 ft. of run of common rafter; also inches and sixteenths are used as a scale with the face of the square upwards (*Fig.* 234).

Rise per foot run – Rise in inches per foot run (Fig. 172)

To find the rise per foot run of a rafter, multiply the rise of the rafter by 12 and divide the result by the run, thus:

$$\text{Rise per foot run} = \frac{\text{rise} \times 12}{\text{run}}$$

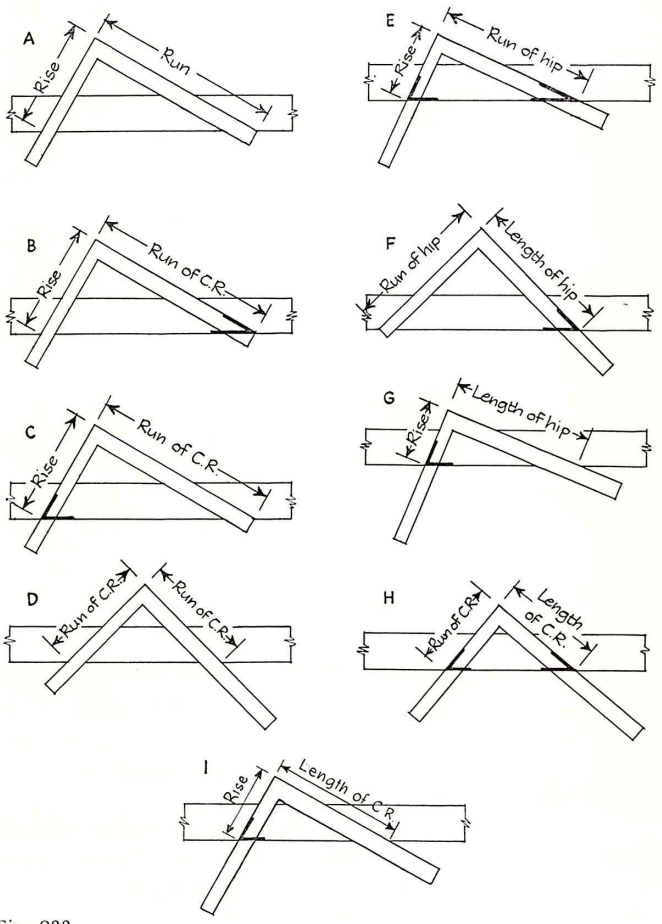


Fig. 233

Use of steel square on even-pitch roofs
Measurements and cuts

(A) *Length of common rafter*
Take rise *and* run

(B) *Seat cut of common rafter*
Take rise *and* run
(Mark on run)

(C) *Plumb cut of common rafter*
Take run *and* rise
(Mark on rise)

(D) *Run of hip or valley*
Take run *and* run *of C.R.*

(E) *Length of hip or valley*
Take rise *and* run *of hip*
Seat cut of hip or valley
Take rise *and* run *of hip*
(Mark on run)
Plumb cut of hip or valley
Take run *and* rise *of hip*
(Mark on rise)

(F) *Edge cut of hip or valley*
Take run *of hip and* length
of hip (Mark on length)

(G) *Hip-backing angle*
Take length *of hip and* rise
(Mark on rise)

(H) *Edge cut of jack rafter*
Take run *of C.R. and* length
of C.R. (Mark on length)
Edge cut of purlin
Take length *of C.R. and* run
of C.R. (Mark on run)

(I) *Side cut of purlin*
Take length *of C.R. and* rise
of C.R. (Mark on rise)

NOTE: *The cut required is against the last name in each case*

The rise and the run are expressed in feet and the factor 12 is to obtain a value in inches.

Example (1) If the rise of a roof is 8 ft. with a run of 8 ft. what is the rise per foot run?

$$\text{Rise per foot run} = \frac{8 \times 12}{8} = 12 \text{ in.}$$

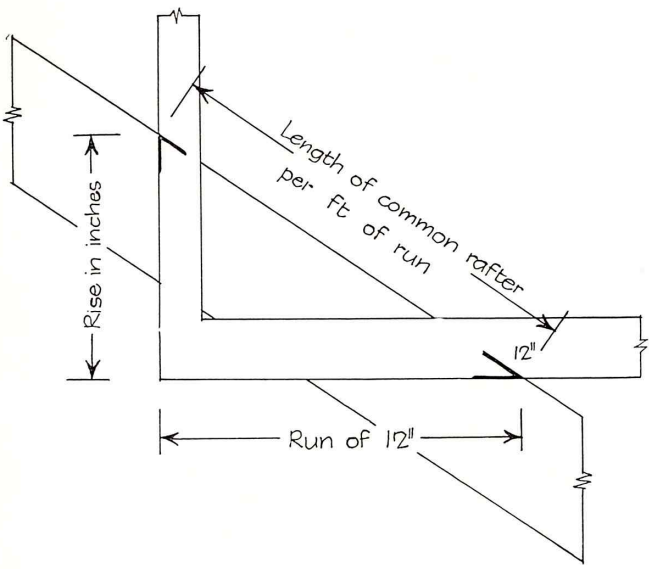


Fig. 234

Scale length of common rafter per foot run

Example (2) Find the rise in inches per foot run of a roof with a rise of 6 ft. and a run of 12 ft.

$$\text{Rise per foot run} = \frac{6 \times 12}{12} = 6 \text{ in.}$$

The rise per foot run is always the same for a given pitch, as shown below:

Pitch	½	⅓	¼	⅙
Rise in inches per foot run	12	8	6	4

Setting out common rafter

There are two methods of finding the length of the common rafter:

(1) Application of the square as many times as there are feet of run.

(2) The scale method (measuring across the square).

(1) *Application of square (Fig.* 235)

With the gauges or fence on the square set to 12 in. on the body and, say, 6 in. (rise in inches per foot run) on the tongue, the square is applied as many times as there are feet of run, each position being marked carefully to obtain accurate results. When there are 9 ft. of run the square is applied nine times as shown. The plumb cut on the lower end of the rafter is marked by a further move of the square along the rafter. To mark the seat cut, the square is moved back to one-third the depth of the rafter.

Odd inches of run (Fig. 236)

When, for instance, the run is 9 ft. 10 in. the square is applied 10 times but the plumb cut mark is made from the 10 in. gradation on the body of the square at the

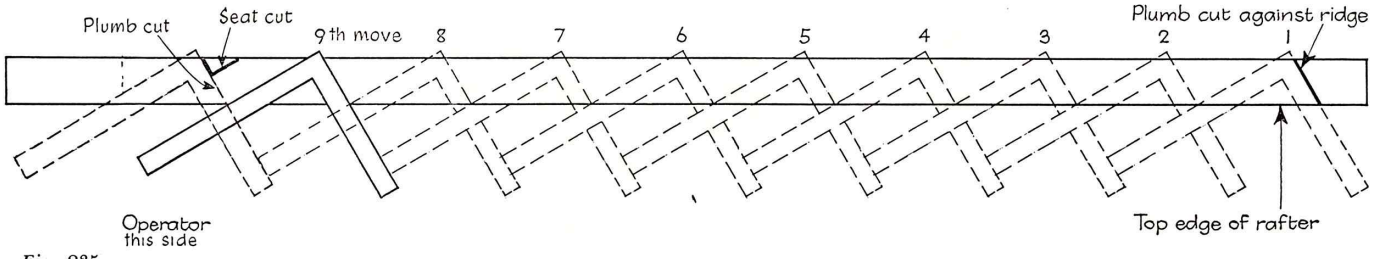


Fig. 235

Square applied as many times as there are feet of run

last application. Allowances for shortenings are made in the usual manner.

(2) *Scale method*

Example: What is the length of a common rafter in a roof of $\frac{1}{4}$ pitch with a span of 18 ft.?
Pitch x span $= \frac{1}{4} \times 18 = 4$ ft. 6 in. rise.

$$\text{Rise in inches per foot run} = \frac{\text{rise} \times 12}{\text{run}} = \frac{4\frac{1}{2} \times 12}{9} = 6 \text{ in.}$$

On the body of the square take 12 in. for 1 ft. of run and on the tongue 6 in. for the rise per foot run. The diagonal distance between the points is the length of the common rafter per foot run. This distance measures 13·42 in. As the run of the rafter is 9 ft. its actual length equals 9 times length of rafter per foot run $= 9 \times 13{\cdot}42 = 120{\cdot}78$ in. $= 10$ ft. $0{\cdot}78$ in. (exclusive of overhang).

Note: The plumb and seat cuts of the rafter are represented in Fig. 235.

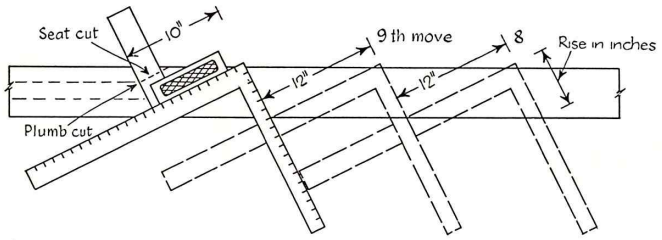


Fig. 236

Odd inches of run

***Length of hip or valley rafter per foot run* (Fig. 237)**

The run of a common rafter is at right angles to the plate line of the building, but the run of a hip or valley rafter is at an angle of 45° to the wall plates when the corner of the building is square.

For every 12 in. of run of the common rafter, the hip rafter has 16·97 in. (considered as 17 in.) of run, because in a right-angled triangle with adjacent sides of 12 in. the length of the hypotenuse is 16·97 in.

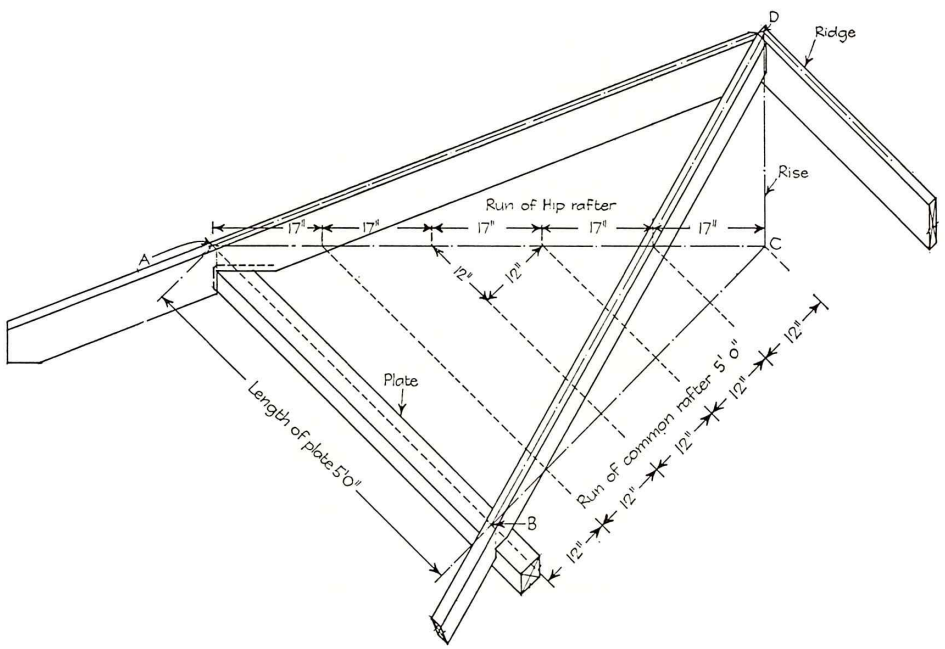


Fig. 237

Length of hip rafter per foot run of common rafter

The hip rafter has the same rise as the common rafter, so that the hip will rise the same amount in 17 in. as the common rafter does in 12 in. The settings on the framing square for obtaining the length of the hip rafter are the rise of the common rafter in inches per foot of run and 17 in., which represents the run of the hip rafter (*Fig.* 238).

The length of a hip or valley rafter is then obtained by repeated applications of the square in the same manner as with the common rafter. The number of times the square is applied corresponds with the number of feet of the common rafter run.

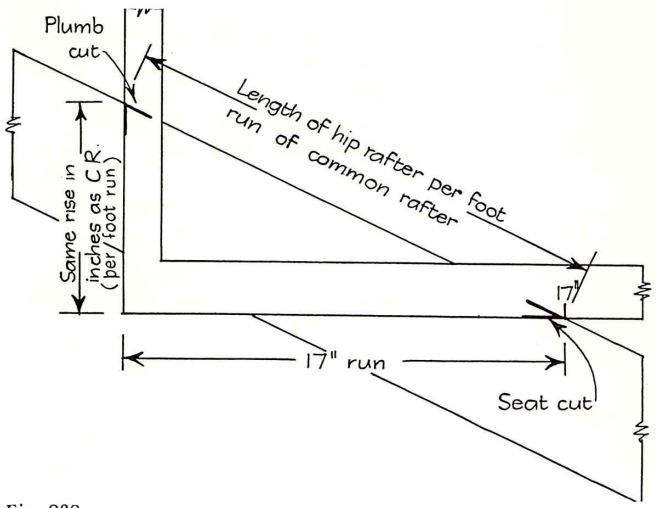


Fig. 238

Length of hip rafter per foot run of common rafter

Odd inches of hip rafter run

If a roof has a span of 18 ft. 9 in. the run is 9 ft. $4\frac{1}{2}$ in. The settings on the square are made to the rise in inches per foot of run and 17, and when marking out, nine applications of the square are made.

We now have to find the run of the hip for a $4\frac{1}{2}$ in. run of common rafter. This can be done by arithmetic or more simply by making a right-angled triangle on the square with adjacent sides equal to $4\frac{1}{2}$ in. The length of the hypotenuse, in this case $6\frac{3}{8}$ in., gives the run of the hip for a $4\frac{1}{2}$ in. run of common rafter. The plumb mark on the hip is then made through the $6\frac{3}{8}$ in. mark on the body of the square when the square is moved to the tenth position.

The length of the hip or valley rafter may be checked by measuring across the square from points 17 and 6, which gives the length of a hip or valley rafter per foot run of common rafter. This length, when multiplied by the run of the common rafter, gives the actual length of the hip or valley rafter.

When the rafter has been set out, allowances are made for shortening in the usual manner.

Jack rafters

Each line that represents a rafter on the plan of a roof is the run of that particular rafter. Consequently it is a simple matter to draw a plan of a roof to a large scale and measure the run of each jack rafter. When the run is known the length of the rafter is set out by repeated applications of the square, as was done with the common rafter, the number of applications in each case depending on the number of feet of run; the settings on the square being the same as those used for the common rafter.

Another method of finding the run of a jack rafter is to find its distance from the corner of the building. This distance is equal to the run of a jack rafter (*Fig.* 239). The diminish of jack rafters is found by dividing the length of the common rafter by the spaces between the jack rafters from the corner of the building to the first common rafter. This only applies when jack rafters are equally spaced.

Rafter cuts

The method of obtaining the cuts for the different rafters when using this method is set out in the following table.

Rafter lengths and cuts in equal-pitch roofs

The following Table 8 is a summary of the information required to determine the lengths and cuts as explained in this second method.

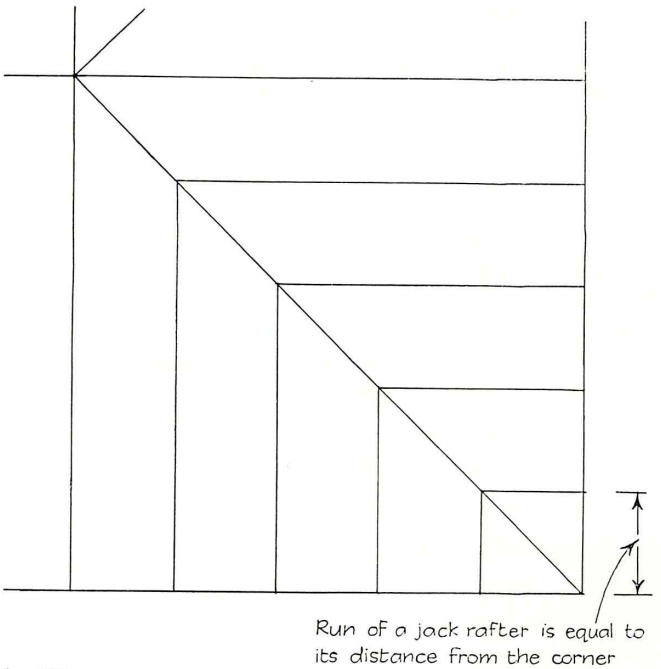


Fig. 239

Part plan of jack rafters

Table 8

Lengths and cuts of rafters

LENGTHS

Required length	Take on body	Take on tongue	How length found
Common and jack rafters	12 in.	Rise for run of 12 in.	Step out once for each foot of run.
Hip rafter run	12 in.	12 in.	Hypotenuse of triangle, i.e., 17 in.
Hip rafter length	17 in.	Rise per foot of run	Step out once for each foot run of common rafter.

CUTS

Cut required	Take on body	Take on tongue
Common rafter seat cut	*12 in.*	Rise per foot of run.
Common rafter plumb cut	12 in.	*Rise per foot of run.*
Hip rafter seat cut	*17 in.*	Rise per foot of run.
Hip rafter plumb cut	17 in.	*Rise per foot of run.*
Hip edge cut	Hip run 17 in.	*Hip length for that run.*
Hip backing angle	Hip length	*Rise.*
Jack rafter edge cut	Common rafter run, i.e., 12 in.	*Length of rafter for 1 ft. of run.*
Purlin mitre cut (Top cut)	*Common rafter run, i.e., 12 in.*	Length of rafter for 1 ft. run.
Sarking mitre cut	Same as the purlin mitre (top cut)	
Purlin side cut (down cut)	Common rafter length	*Common rafter rise for that length.*

To mark these cuts, draw a line along the edge of th e body or tongue where italics are used in this table.

Roof-covering materials

The following materials are used:
Corrugated galvanised iron.
Corrugated aluminium.
Strip roofing of galvanised iron or aluminium.
Corrugated mineral fibre cement sheets (asbestos cement sheets).
Corrugated bitumen protected steel.
Corrugated (opaque) plastic sheets.
Corrugated sheets of acrylic resin (transparent plastic).
Glass fibre reinforced synthetic resin sheets (translucent) for roof and wall lights in corrugations of standard patterns.
Tiles of concrete, burnt clay or metal.
Bituminous felt.
Mastic asphalt.
Sheet copper, zinc galvanised iron.
The selection of a particular type of roofing material is influenced by such factors as:

(1) Pitch of the roof.
(2) Durability of the material.
(3) Exposure to high winds, sea, air, or industrial fumes.
(4) Maintenance costs.
(5) Fire hazard.
(6) Weight.
(7) Appearance.
(8) Initial cost.

Corrugated iron *(24 and 26 gauge)*

Sheets of corrugated iron are galvanised by being dipped in a bath of molten zinc. Standard sheets vary in length from 5 ft. to 12 ft. in 1 ft. increments, and have a width of 2 ft. $1\frac{1}{2}$ in. The measurement from centre to centre of the corrugations is 3 in. and the depth $\frac{3}{4}$ in. Both edges of the sheet are turned in the same direction.

Sheets are said to be laid with a side lap of one-and-a-half corrugations when they cover an effective width of $22\frac{1}{2}$ in. and with a side lap of 2 corrugations when they cover 21 in. The latter cover should be used in exposed positions and when the slope of the roof is slight. In these cases the exposed edge of the sheet should if possible be turned away from the prevailing wind. Ends and side laps of sheets should be painted with red lead and boiled linseed oil or good-quality roof paint. Sheets are secured to purlins or sarking with $2\frac{1}{2}$ in. or 3 in. lead-headed and preferably galvanised nails driven through the tops of the corrugations.

Before galvanised iron is painted the weather should be allowed to etch the surface for at least six months; otherwise the paint will not adhere to the smooth, galvanised surface. If painting has to be done sooner, an acid wash should be applied. Great care should be taken to wash off all remains of acid from the etched surface. A suitable acid wash is 4 oz. of copper sulphate to a gallon of water.

In addition to standard sheets, special sheets are also available in lengths from 6 ft. to 30 ft. These sheets have

extra corrugations giving an effective coverage of 2 ft. 6 in. compared with the 1 ft. 10½ in. of the standard sheet.

Corrugated aluminium

Sheets of corrugated aluminium are available in standard sizes and gauges and of two widths; one is of standard size with eight corrugations in the width and the other, which is 6 in. wider, has ten corrugations.

Aluminium sheets should be secured with aluminium-alloy nails with spring head washers of the same material.

Before the surface of aluminium is painted it should be etched either by exposure to the weather or by an acid wash. A suitable wash consists of a very dilute solution of phosphoric acid and water. The surface of the metal should be first cleaned with a solution of washing soda and water and then etched with the solution of phosphoric acid brushed on. Great care should be taken to wash off all the remains of the acid wash before the surface is painted with a zinc chromate primer (undercoat).

Strip roofing

This type of covering is applicable to roofs of any pitch. Lengths of up to 60 ft. are normal thus end laps can be avoided. Special fixing clips are used fixing to either wood or metal.

Mineral fibre cement sheets

(1) Although the original cost is high the maintenance cost is low.
(2) They are unaffected by sea air.
(3) They are unaffected by chemical fumes.
(4) Painting is not required.

Corrugated sheets of mineral fibre are classified as to size and shape of the corrugation according to the following Table 9.

Table 9

Corrugated sheets

Type of sheet	Depth of corrugation	Centre to centre of corrugation
Small section	Under 2 in.	2⅞ in. and 3 in.
Large section	2 in. and over	5¾ in., 6 in., and 7 in.
Angular section	2 in. and over	13½ in. to 15 in. depending upon the width of sheet.

The thickness of corrugated sheets of small section is 7/32 in. and of the large and angular section type of sheet ¼ in.

Fixing of sheets

Sheets are usually secured by galvanised screws of No. 12 screw gauge or ¼ in. diameter bolts. Under the head of each bolt or screw there is a metal washer, beneath which is a washer of bituminous felt, or similar material, to make the fastening watertight. Screws must not be driven with a hammer but turned with a screwdriver. Holes for screws and bolts must be drilled and not punched. The amount of end lap given to a sheet depends upon the pitch of the roof as shown in the following Table 10.

Table 10

Lapping of sheets

Inclination of roof in degrees	End lap in inches
30 and over	6
Under 30 and over 15	9
15 and under	12

Where the inclination of the roof is less than 30° but is more than 15° the end laps may be reduced to 6 in. if they are sealed with a continuous strip of waterproofing mastic compound of a bituminous or similar nature. Where the inclination does not exceed 15° end laps may be reduced to 6 in., provided both end and side laps are waterproofed as described above.

In addition to roofing sheets there are available various mineral fibre cement roofing accessories which include items such as ridge and hip cappings, barge and cover boards, eaves and box gutters, down pipes, skylights, and various types of ventilators. Curved sheets are also available.

Ridge coverings and similar accessories should be securely fastened with bolts or screws in the same manner as recommended for the sheets, and joints made watertight with a mastic compound or similar material.

Safety precautions

On account of the brittle nature of mineral fibre sheets safety precautions are enforced in certain types of buildings by requiring sarking under the roofing material, purlins placed closer than usual, or metal mesh placed over the purlins before the roofing is fixed.

Safety precautions do not apply to:
(1) Single-storey buildings of a floor area of less than 1,500 sq. ft. which:
(a) Have a ceiling framing;
(b) Have a storey height of not more than 9 ft.; and
(c) Are so situated that no other structure can be erected within 10 ft. thereof.
(2) Those portions of roofs which are at an angle exceeding 45° to the horizontal.

Safety requirements

When sarking is used the grade of timber must be not lower than Building B and the sarking must be fixed to the whole of the roof. The boards should not be less than 6 in. wide and if fixed by the "hit and miss" method spaced not more than 8 in. apart. The thickness of sarking is dependent upon the spacing of rafters, and for rafters spaced not more than 1 ft. 6 in., ½ in. sarking may be used; for spacings 1 ft. 6 in. to 2 ft. 6 in., ¾ in. sarking; and for spacings from 2 ft. 6 in. to 3 ft. 6 in., 1 in. sarking. Where the roof covering is to be fixed directly on to the purlins they should be spaced so that the clear horizontal distance between purlins is not more than 12 in. Where a metal mesh covers the purlins the distance between the purlins may be increased to 3 ft. for small sections and 4 ft. for large sections.

The metal mesh used to cover the purlins must be corrosion resistant and be constructed of woven, interlocked, or welded wire, or alternatively of expanded metal. The gauge of such wire must be between the limits of 10 S.W.G. for 12 in. mesh and 18 S.W.G. for a $1\frac{1}{2}$ in. mesh wire with intermediate meshes having an equivalent cross-sectional area of metal. The mesh must be tightly stretched over the roof and securely fixed to purlins and other structural members at 12 in. centres.

Use of cat ladders

A cat ladder is a plank or board used by a workman on a roof to prevent him sliding, or falling through the roof. Such a ladder is usually a long board about 11 in. wide with battens or slats spaced at about 12 in. intervals across its face. An arrangement at the top end of the board holds it to the ridge but does not prevent it being moved from one position to another.

It is essential that all men working on corrugated mineral fibre roofs use cat ladders or similar devices to ensure safe working conditions.

Tiles (Clay or Concrete)

Clay tiles are usually made to the Marseilles pattern and those of concrete to a similar interlocking design. Used in conjunction with tiles are various specially made ridging and hip tiles, apex caps, and end stops.

Tiles cannot slide down the roof because they are held by lugs, on the underside of each tile, which rest against the tile battens. The tiles are secured to the roof by means of 18 S.W.G. copper or galvanised iron wire which is threaded through a hole in a lug on the underside of the tile and tied around the tile batten. Each alternate tile in every row of tiles should be so tied.

In exposed positions it is sometimes considered advisable to bed tiles in cement mortar.

The slope of a roof for tiles should not be less than 32° to the horizontal. Tile roofs have a long life, involve low maintenance costs, and when glazed or painted are non-absorbent.

Tiles (metal)

A common form of metal tile is of moulded galvanised iron coated with bitumen and stone chips. Metal tiles can be fixed to roof slopes as low as 15°. They are nailed to battens and form a lightweight attractive roof covering.

Bituminous felt roof coverings

Bitumen-impregnated felt is made in two- and three-ply thicknesses in rolls usually 36 in. wide. Such felts are laid in overlapping strips, the first layer being "spotted" with hot bitumen so that it may move to a certain extent, under atmospheric changes, without damaging the material. The covering layers are set in hot bitumen.

A roof covering of bituminous felts (fabric roof) usually comprises three layers of two-ply felt cemented together with melted bitumen. The top surface is usually coated with bitumen and gravel embedded on the surface. Cold processes are used in special conditions.

Mastic asphalts

A mastic asphalt is a mixture of fine aggregate and bitumen that is applied with hand tools when the asphalt is hot. Such an asphalt may be made of a comparatively low bitumen content rock asphalt mixed with lake asphalt of high bitumen content, together with an asphaltic flux oil to make the mixture workable, or on the other hand may consist of a lake asphalt to which graded aggregates and an asphaltic flux oil are added. Mastic asphalt may also be made of petroleum residual bitumen mixed with graded aggregates. It can only be used on comparatively flat roofs and applied hot in two layers.

Sheet metal

Flat sheets of galvanised iron, copper, lead, and zinc are not used to any extent for roof coverings of dwellings except for small areas to be covered, over porches or windows.

Skylights

The use of corrugated transparent and translucent materials for skylights on pitched roofs has largely replaced the conventional type of skylight, but for flat roofs a metal frame is made for the support of sheets of wire-reinforced glass of various kinds.

Practical roof work

In this section of the book a description will be given of the actual setting out of a hip roof, a typical plan of which is shown in *Fig.* 240.

(1) *Setting out rafter positions*

Before the walls of the building are erected the rafter positions should have been set out on the top wall plates.

The end wall plate of a roof where a hip occurs is set out by first marking a point distant from the ends by one-half the span of the building. This same distance is measured from each corner along the side wall plates and a square mark is made here in each case across the plates.

These marks should be clearly made because they are the *centre* setting-out lines of the end and first common rafter positions on each side and end of the building (*Fig.* 241). Since such lines, when continued, intersect the centre lines of the hip rafters at the apex of the roof one must work accurately to avoid errors. After the half thickness of each rafter has been marked on each side of the positions previously marked, the jack rafter

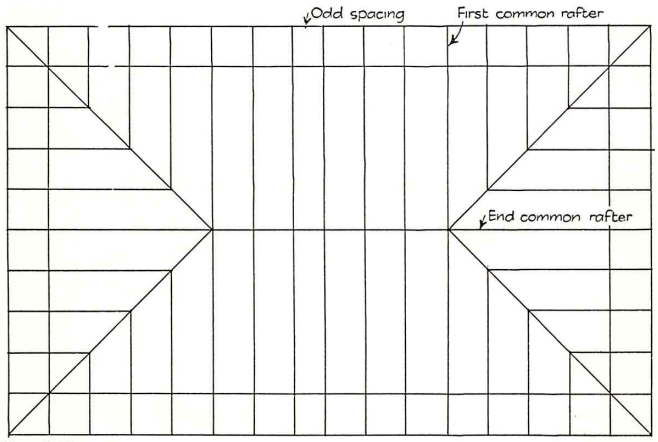


Fig. 240

Plan of hip roof

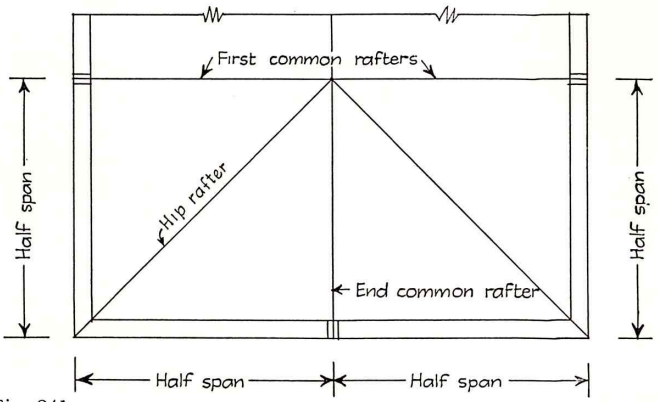


Fig. 241

Centre setting-out lines for equal-pitch roof

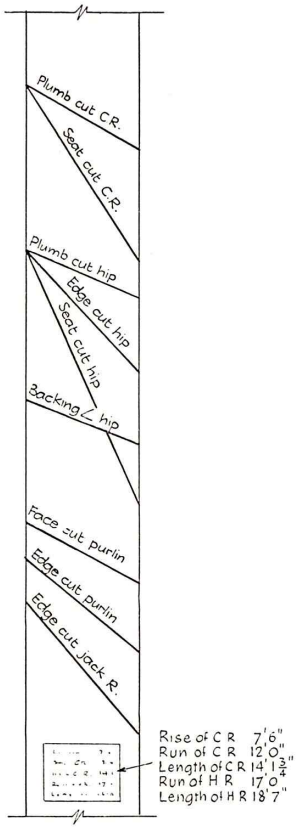


Fig. 242

Example of rafter cuts set out on a wide board and list of measurements

positions are set out at 18 in. (to suit a tile roof) from the common rafter positions. An odd spacing may occur at the corners of the building but this is ignored.

When the jack rafter positions have been set out on *both ends* and sides of the building, the positions of the common rafters on each side of the building are set out at 18 in. centres. Rafters are spaced equally, but should there be an odd spacing which is less than the normal spacing at the end of the run, it is ignored.

Wherever possible, arrange rafters alongside ceiling joists so that the joists will have the effect of tying the rafters together.

(2) *Rafter cuts*

The length and cuts of roof members may be set out by any of the methods already described and a good tradesman will have the cuts of rafters marked on a board and also the lengths of rafters written down, as shown in *Fig.* 242. To avoid confusion it is advisable to write a name against each cut as shown.

(3) *Common rafters*

It is a good practice first to set out and cut a pair of common rafters and then test the accuracy of the setting out by temporarily fixing them in place, with a piece of ridgeboard at their upper ends. Should the test prove correct, one of the rafters is used as a pattern from which the remainder of the common rafters are cut. When marking rafters from a pattern keep the top edges flush so that the height above the seat cut is constant, and always arrange to have the round edges uppermost so that, when the rafters are erected, they will tend to be straightened by their own weight or that of the roof covering.

The lower ends of all rafters are usually left longer than required until all the roof members have been fixed, when the ends of rafters are cut off to a straight line.

Remember that each common rafter must be shortened to allow for the half thickness of the ridge, the exception being the common rafter at the end of the building which must be shortened, to a greater extent than other common rafters, by one-half the thickness of the first common rafter on the side of the building (*Fig.* 243).

(4) *Jack rafters*

It is usual to mark the lengths of all jack rafters on the common rafter pattern, that is, before it has been short-

ened. The jack rafter lengths may be taken either from the long or short point of each cut as explained previously. See page 133.

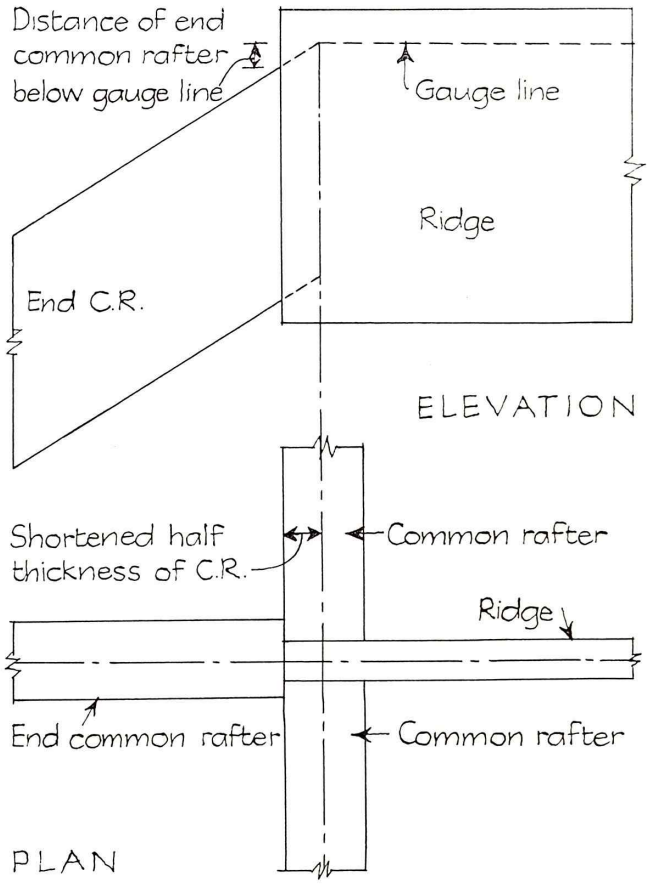


Fig. 243

Shortening of end common rafter

(5) *Ridge*

Length

The length of the ridge is found by measuring the distance between the centre setting-out lines of the first common rafters, at each end of the roof, and then adding 2 in. to allow for half the thickness of the first common rafters at each end of the ridge *(Fig.* 244). Shown in *Fig.* 245 is one common rafter arrangement used at the apex of a roof where the hip and common rafters meet. Other rafter arrangements that may be used at the apex of a roof are shown in *Figs.* 246 A, B.

Setting out

It is common practice to place the ridge alongside the wall plate and to transfer the common rafter positions from the wall plate to the ridge simply by squaring the lines over from one to the other *(Fig.* 247). Mark the rafter positions on both sides of the ridge. From the top edge of the ridge a line must be gauged on both sides of the board to which the top edges of the rafters are fixed. The distance from the top of the ridge depends upon whether the roof is to be sarked and the kind of roof covering to be used.

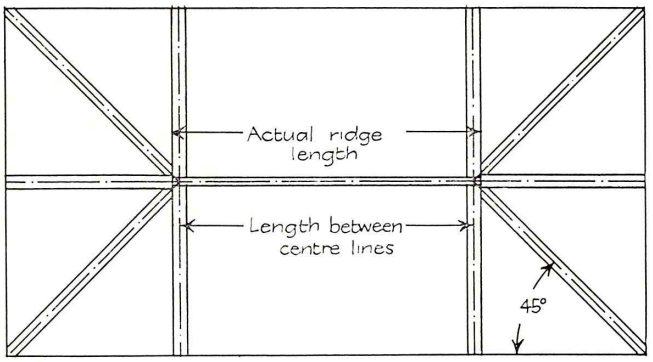


Fig. 244

Variation in actual and set-out length of ridge on centre lines

Joints and timber

When a ridge has to be lengthened it is either scarfed or butted, and the joint is strengthened by pieces of timber of the same dimensions as the ridge placed on either side about the joint *(Fig.* 248). Timber for a ridge should be at least 1 in. thick and 2 in. greater in depth than the common rafters attached to it. (See N.Z.S.S. 1900, Chapter 6.1.)

(6) *Shortening of rafters*

Rafters must be shortened or reduced in length to allow for part of the thickness of timbers against which they are framed.

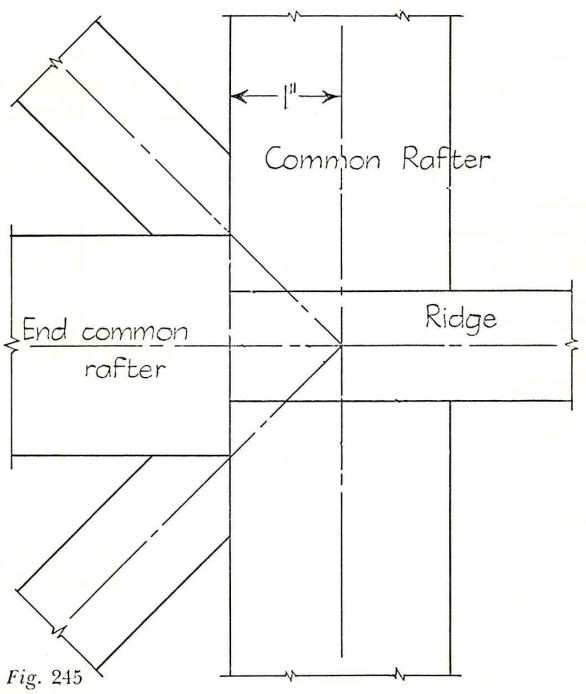


Fig. 245

Common arrangement of hip and common rafters at apex of roof

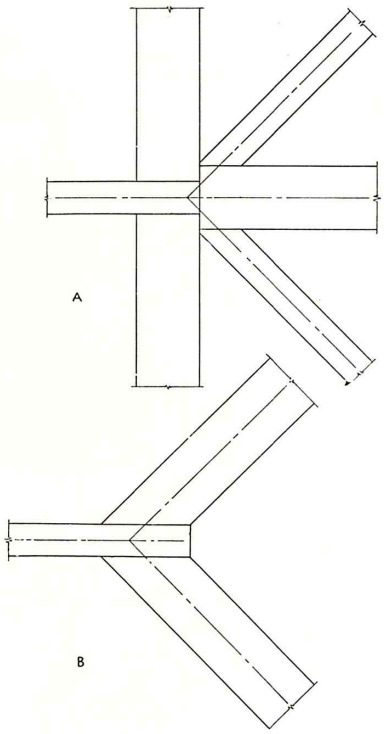


Fig. 246

Various rafter arrangements at apex of roof

(A) *Hip rafters framed to end common rafter*

(B) *Hip rafters framed to ridge*

Common rafters

It will be seen in *Fig.* 249 that the common rafter must be shortened by half the thickness of the ridge.

Note the method of measuring this distance square off the plumb cut.

Hip rafters

As shown in *Fig.* 250 the hip rafters must be shortened by a distance equal to half the 45° thickness of a common rafter. This distance is always measured square off the hip plumb cut as shown and made before the edge cuts are marked.

Jack rafters (*Fig.* 251)

Jack rafters must be shortened to allow for the half thickness of the hip rafter. As jack rafters always meet the hip at 45° the jack rafters must be shortened by half the 45° thickness of the hip rafter, this distance being deducted from the jack rafter in a horizontal direction as in the cases of other shortenings.

(7) *Pitching the roof*

A roof may be pitched by any of the following methods:

(a) A long and heavy ridge may be propped in position and the rafters secured to it (*Fig.* 252).

(b) Pairs of rafters may be set up at the ends of the ridge, to support it, while the remaining rafters are nailed.

(c) Sometimes the ridge is nailed to the upper ends of rafters before they are erected and then the whole or part of one side of a roof, as can be conveniently handled, is first raised and then propped in position while the rafters on the opposite side of the roof are secured. Where the roof construction is not held by an end common rafter (e.g., gable roof) it is first made plumb and then temporarily braced in its correct position.

(8) *Hip*

The theoretical method of finding the lengths of the hip rafters, outlined in previous discussions, is not always followed in practice; mainly on account of the difficulty of having the plates and roof construction perfectly level and square in all respects. The method used on most jobs is to erect the main common rafters and ridge as described, and then to measure with a steel tape the length of each hip (*Fig.* 253). Any slight variation in length is thus corrected. This measurement is applied to the hip rafter as shown in *Fig.* 254.

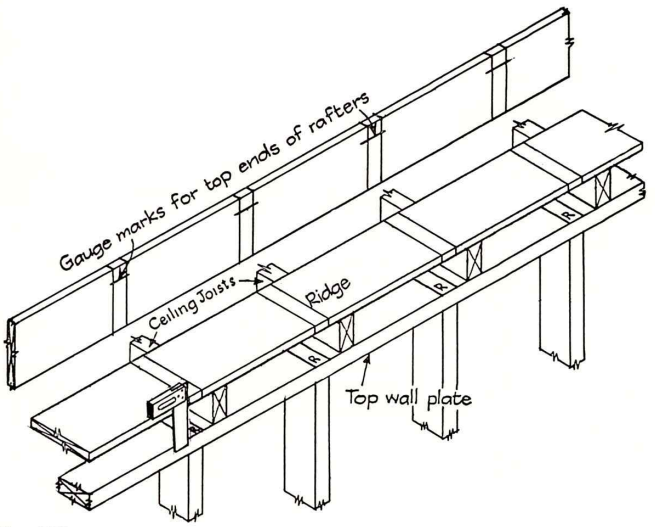


Fig. 247

Rafter positions marked on wall plate transferred to ridge board

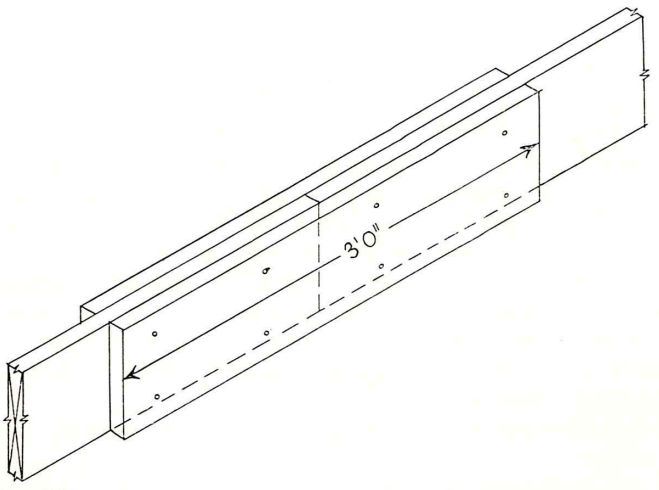


Fig. 248

Method of joining ridge

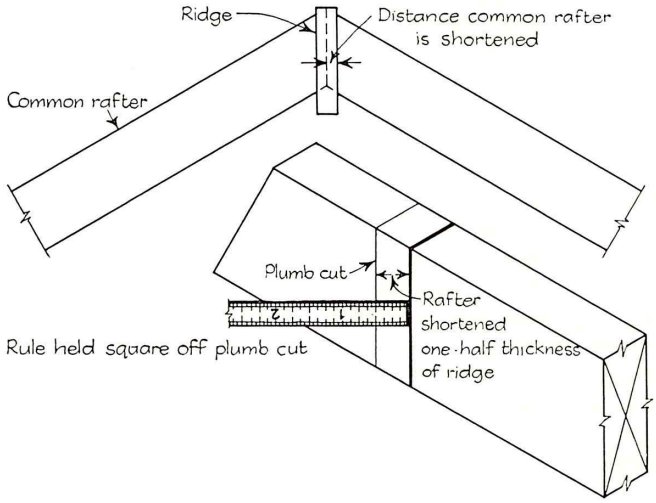


Fig. 249

Shortening common rafter

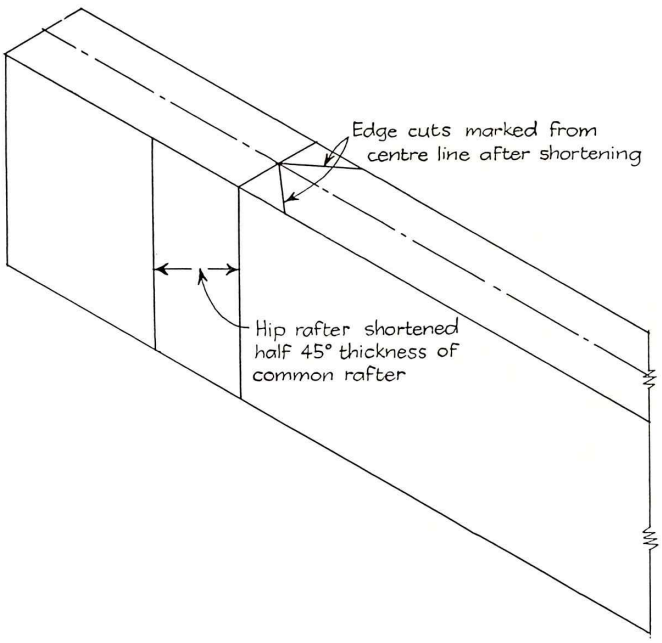


Fig. 250

Shortening hip rafter

Lowering hip rafter

When purlins are fixed on the rafters the top edges of all the hip rafters are kept to the same line or above that of the purlins, but when tile battens or sarking are used the corners of the top edge of each hip rafter are removed or the rafter lowered so that the corners will not project above the general line of the other rafters in the roof. As it is more costly and difficult to bevel (or back) a hip rafter than to lower it, lowering is usually done by:

(a) Making the seat cut higher and thus lowering the rafter; or

(b) Reducing the length of the rafter and thus lowering it.

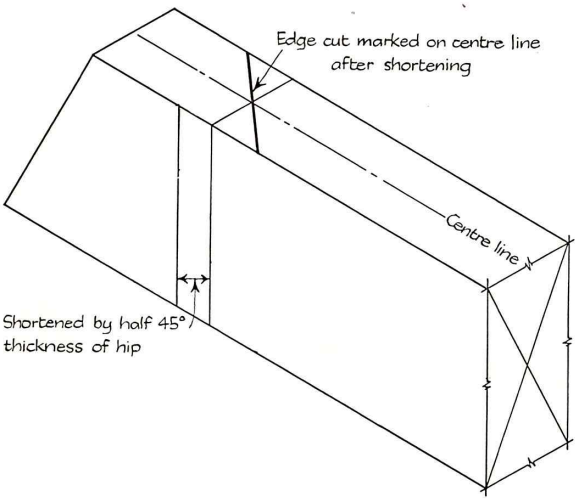


Fig. 251

Shortening jack rafters

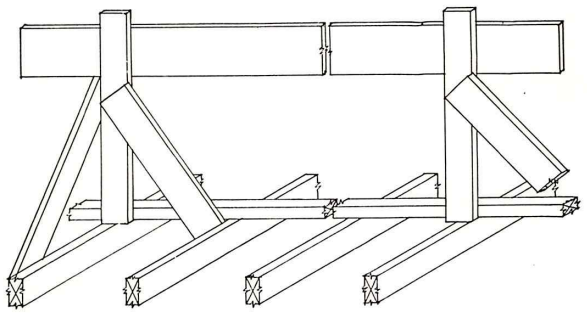


Fig. 252

One method of supporting ridge

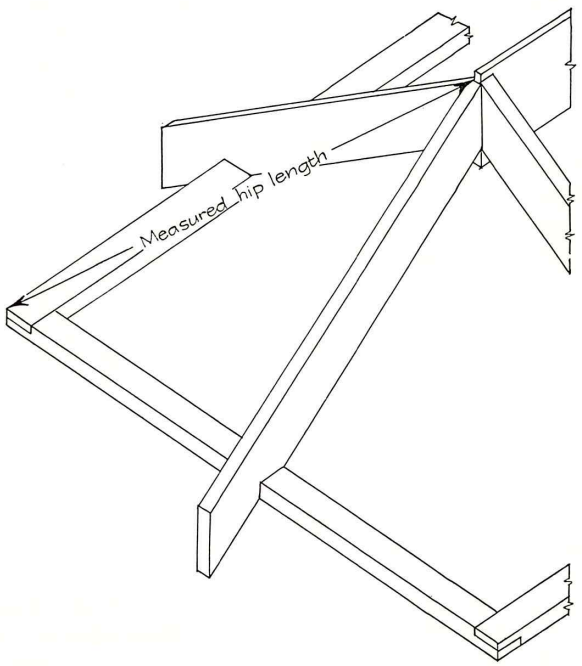


Fig. 253

Measuring length of hip rafter

(a) The depth of the seat cut on a hip rafter is the same as that of the common rafter and instead of measuring the depth of the seat cut on the line CD (*Fig.* 255) it is measured on the line AB.

(b) In addition to the usual amount of shortening made to a hip rafter, a further reduction is made to lower it. *Fig.* 256 shows the place of a hip at the corner of the building, and to make the top edges of the rafter line up with other rafters, the length is reduced by the distance cd, which has the effect of lowering the rafter. As the distance cd is the side of a square, the other side of which is equal to half the thickness of the rafter, the rafter is shortened by this distance in addition to the usual shortening. *Fig.* 257 shows how the shortenings are made from the top end of the rafter.

After the hip rafters have been secured the jack rafters are then fixed, but not before each hip has been straightened to a line stretched along its entire length.

(9) *Under purlins*

When the span of rafters exceeds that given in the table of maximum spans for the various sizes of rafters (N.Z.S.S. 1900, Chapter 6.1, Table 7) the rafters are supported centrally by either 4 in. x 3 in. or 4 in. x 2 in. under-purlins and struts.

The purlin positions are marked under each hip, gable, or valley rafter and then the length of each purlin is measured with either a steel tape or a measuring rod, taking care to measure at either the top or bottom edge of the purlin in each case.

When fixed at the ends, these purlins are straightened on the side and edge, either before the rafters are nailed to them, or when the rafters are being straightened. Long purlins may require temporary supporting struts. The sides of all rafters must be sighted for straightness before they are nailed to the purlins.

(10) *Struts*

Struts are inclined compression members of a roof which support the purlins under the rafters (*Fig.* 258). In

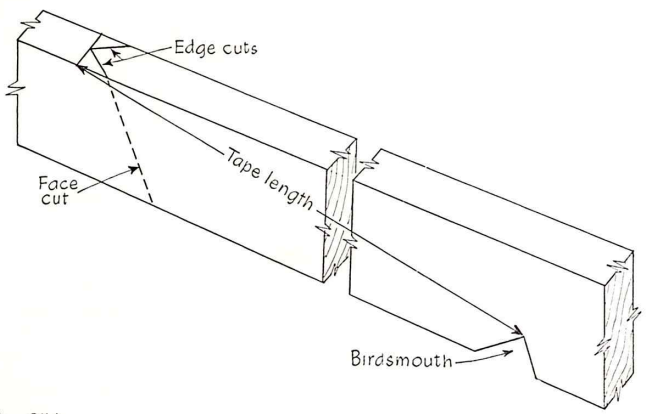


Fig. 254

Transferring length to rafter

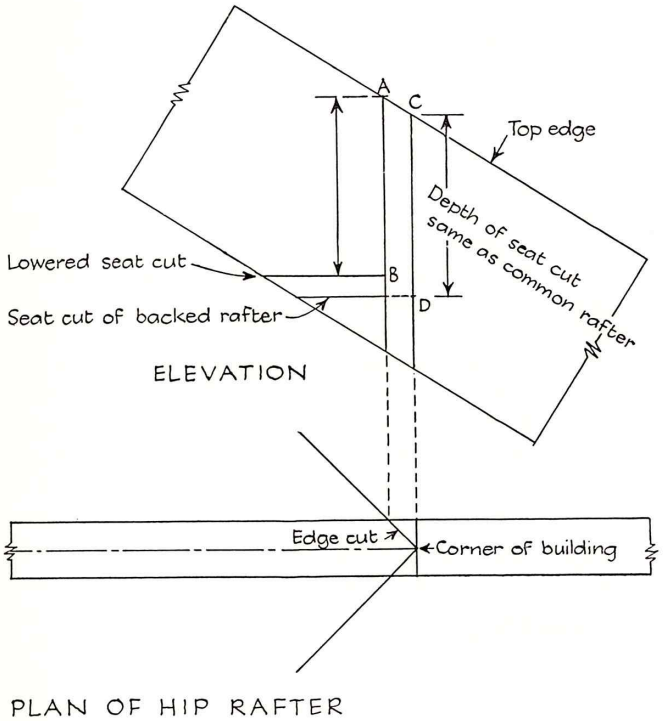


Fig. 255

Lowering hip rafter

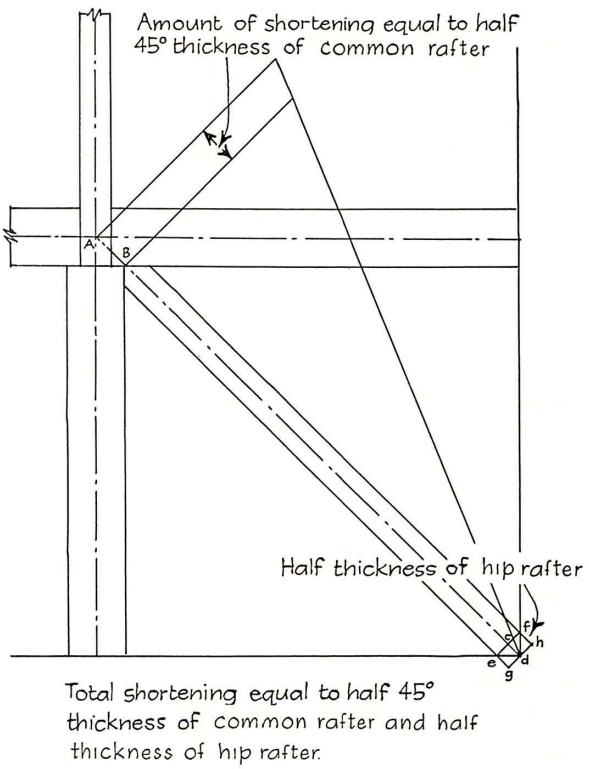


Fig. 256

Shortening to lower hip rafter

cottage work the foot of a strut is usually arranged over an inside partition wall but sometimes a plate is fixed on the tops of ceiling joists, near solid support, to which the lower ends of struts are attached. The system of using purlins and struts permits the use of lighter rafter timbers and consequently effects a saving.

Struts are usually of 4 in. x 2 in. timber spaced at 6 ft. centres. Vertical roof supports are most effective but these are not always possible and consequently struts have to be used; but a strut that is "too flat" ceases to be effective. The fitting of a strut to a plate and a purlin is carried out by placing the strut alongside the particular members and marking their outlines by using a rule as shown in *Fig.* 259. The outlines of the members are first marked on the strut and then its length is found by measuring the distance between the plate and the purlin (AA) and then marking this length on the strut (A:A′) and adjusting the outlines accordingly.

(11) *Collar ties* (*Fig.* 258)
When rafters exceed 10 ft. in length they must have collar ties of not less than 6 sq. in. in cross section fixed at not more than 6 ft. centres. When the length of rafters does not exceed 10 ft. collar ties may be dispensed with, but the rafters must have connecting cleats (*Fig.* 260) fixed just below the ridge and spaced in the same way as collar ties.

(12) *Bracing of roof*
Whether a roof is braced or not depends upon the size and type of roof. It is not necessary to brace a hip roof because the hip rafters serve as braces, but in other instances when the roof is of such size that braces are required, they are placed diagonally, either as a solid brace between the rafters or as a surface brace under them, as shown in *Fig.* 261. Any sarking or wood linings under the rafters (in the place of ceilings) effectively brace a roof. A method of bracing a gable roof is shown in *Fig.* 262.

(13) *Valley rafters*
Should there be a valley rafter, it is lowered so that if the line of the top edges of the jack rafters are continued they will meet in the centre line of the valley, as shown in *Fig.* 263. Valley boards to support the sheet metal valley fixed by the plumber are secured to the top edges of the rafters as shown in *Fig.* 264.

(14) *Trimming of openings* (*Fig.* 265)
The trimming of openings in roofs for chimney stacks and skylights is done by methods similar to those used for trimming openings in floors and walls. Timbers are kept clear of brick or concrete work. The size of the opening for a particular chimney varies according to the pitch of the roof, the greater the pitch, the longer the rectangular opening in the roof.

(15) *Support of flashings*
Chimney flashings are supported at the front and the sides of the chimney by the roof covering and the gutter

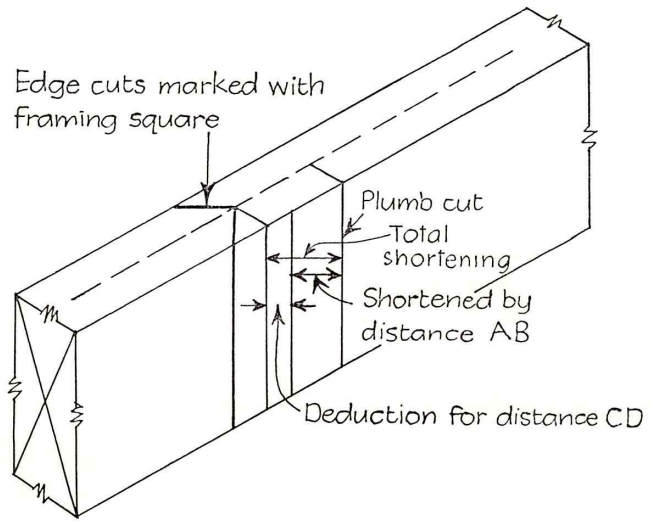


Fig. 257
Diagram showing the total shortenings being made from the top end of a rafter

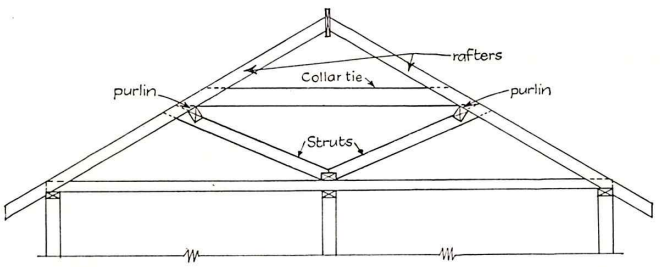


Fig. 258
Strutting a roof

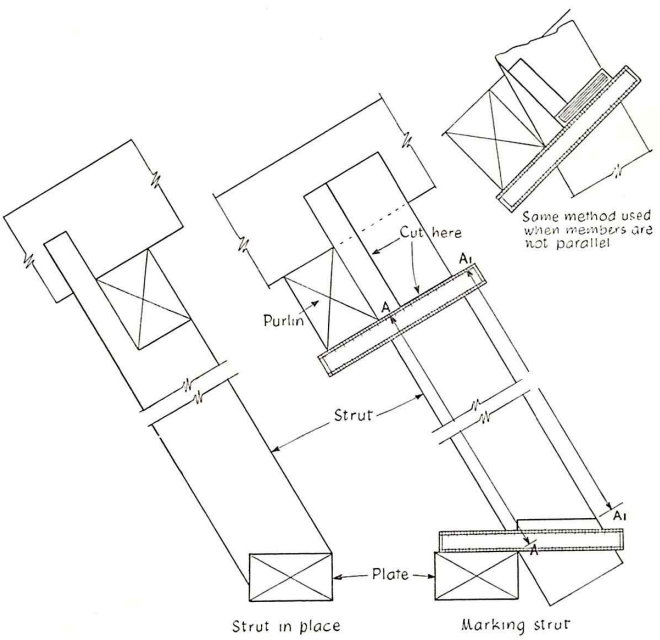


Fig. 259
Method of marking a strut

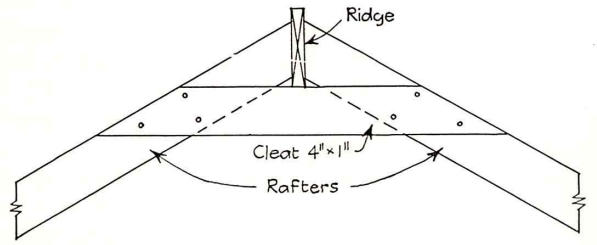


Fig. 260
Positions of cleats

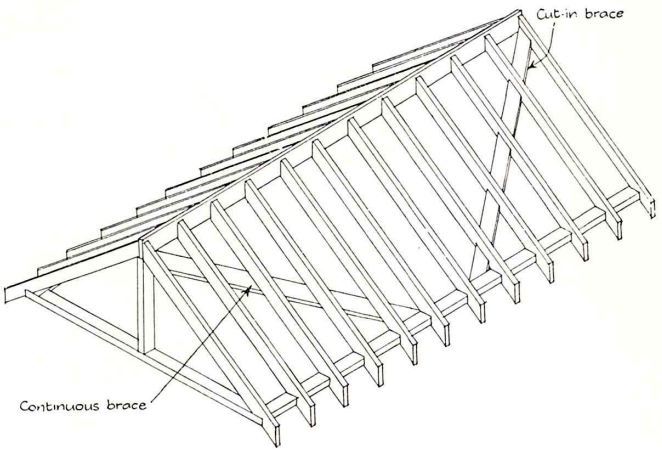


Fig. 261
Methods of diagonally bracing a gable roof

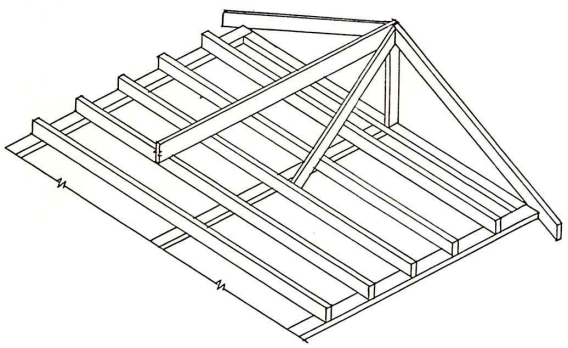


Fig. 262
Bracing one end of a gable roof

at the back of the chimney by 6 in. or 9 in. packing pieces arranged flush with the roof surface. Different methods of flashing are employed with various openings and roofing materials and consequently such support should be arranged to the plumber's requirements.

(16) *Trimming rafter ends*

If the lower ends of the rafters have not already been pre-cut to an exact length they are now sawn to the line of the overhang but not before the rafters have been securely supported and straightened. Lines are stretched from the ends of the roof to the width of the overhang and the lower end of each rafter is then sawn plumb or to the particular shape required.

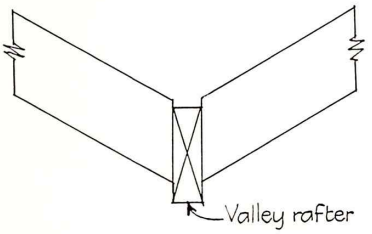


Fig. 263
Position of valley rafter

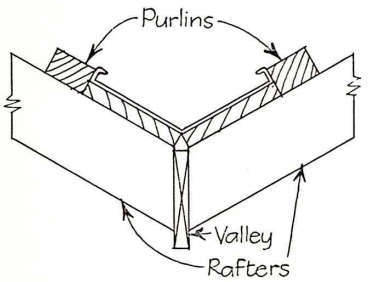
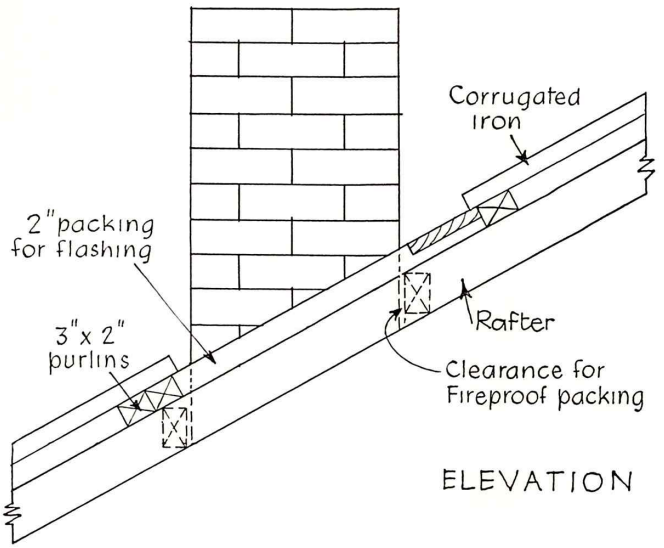


Fig. 264
Valley boards and purlins



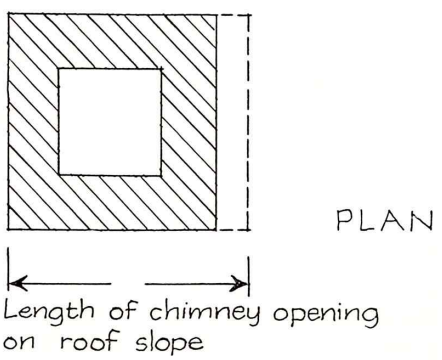


Fig. 265
Trimming for chimney opening in roof

(17) *Fixings for roof coverings*

Roofs that are covered with corrugated sheets of galvanised iron, aluminium, asbestos, or plastic roofing material are either sarked or have purlins. Sarking boards may be either closely laid or laid with spaces approximately equal to the width of a board between them, known as the "hit and miss" method of fixing. Sometimes sarking is laid diagonally on a roof and acts as bracing or it may be fixed parallel with the ridge of the building. Purlins for the support of the roof coverings are arranged on the top edges of rafters parallel to the ridge at spacings to suit the particular type of roofing used.

Table 11

Rise of Rafters per Foot of Run for Various Degrees of Slope

Degree of slope of rafters	Rise in inches per foot of run
2½	½
4½	1
7	1½
9½	2
11¾	2½
14	3
16¼	3½
18½	4
20½	4½
22½	5
24½	5½
26½	6
28¼	6½
30¼	7
32	7½
33¾	8
35¼	8½
37	9
38½	9½
40	10
41½	10½
42½	11
43¾	11½
45	12

Use of table

Example: Assume the roof has a slope of 32°. Refer to 32° in the table and it will be found that such a roof has a rise of 7½ in. per foot of run. If the common rafter has a run of 8 ft. the full rise of the rafter is 8 x 7½ = 60 in. = 5 ft.

All metal roofs must have a layer of approved felt material beneath the roof covering. The sarking is covered with a building paper or bituminous felt before the roofing is fixed, while in the case of roofs with purlins, wire netting must be stretched over these to provide extra support for the paper or felt.

When roofs are tiled, tile battens are fixed on the edges of the rafters at spacings to suit the particular type of tiles being used, and although the carpenter may, on some jobs, secure these battens, in most cases the tilers prefer to do this work.

Table 12

Various Roof Pitches and Length of Common, Hip, and Valley Rafters, per Foot of Run

I Pitch	II Rise in inches per foot of run	III Length in inches of common rafter per foot run	IV Length in inches of hip or valley. (Based on 12 in. of common rafter run.)
1/12	2	12⅛	17⅛
1/8	3	12⅜	17¼
1/6	4	12⅝	17⅜
5/24	5	13	17¾
¼	6	13⅜	18
7/24	7	13⅞	18⅜
⅓	8	14⅜	18¾
⅜	9	15	19¼
5/12	10	15⅝	19¾
11/24	11	16¼	20¼
½	12	17	20¾
13/24	13	17¾	21⅜
7/12	14	18½	22
⅝	15	19¼	22⅝
⅔	16	20	23⅜
17/24	17	20¾	24
¾	18	21⅝	24¾
19/24	19	22½	25½
⅚	20	23⅜	26¼
⅞	21	24⅛	27
11/12	22	25	27¾
23/24	23	26	28⅝
1	24	26⅞	29⅜

Use of table

(1) Example of finding length of common rafter, by means of Table 12:

Pitch of roof = ¼ – (refer to table)
Run of common rafter = (say) 8 ft.
Therefore length of rafter = 13⅜ x 8 = 107 in.
= 8ft. 11 in.
The length of hip or valley rafters = 18 x 8 = 144 in. = 12 ft.

Questions on Chapter 7

(1) On the side elevation of a common rafter show:
  (a) How the length of the rafter is measured.
  (b) Where the rise is measured.
  (c) The run of the rafter.

(2) A gable roof has a ⅓ pitch and a span of 21 ft. Find the length and cuts of the common rafters.

(3) What "shortening" is necessary for the common rafters in a gable roof with a ridge $1\frac{1}{4}$ in. thick? Show how an actual rafter is shortened.

(4) Draw an isometric sketch of one end of a hip roof showing all the roof members. Label the sketch with the names and suggested sizes for a roof with a 20 ft. span.

(5) What is the difference between a couple roof and a collar-tie roof?

(6) Show by a scale drawing a geometrical method of finding the length of:
  (a) A common rafter.
  (b) A hip rafter.

(7) By geometrical means show how to find the respective lengths and edge cut of jack rafters. Assume that the common rafter has a run of 12 ft. and a rise of 5 ft.

(8) By a short-cut geometrical method show how you would find the length and cuts of a hip roof of ⅓ pitch with a span of 18 ft.

(9) In general terms describe:
  (a) A steel or framing square.
  (b) State the various ways in which a framing square may be used.

(10) Using a steel square, how is the length of the common and hip rafters found for a hip roof with a span of 24 ft. and a rise of 5 ft.?

(11) Describe how the steel square is used for finding the various cuts of the common and hip rafters of the hip roof described in the previous question.

(12) How would you bevel the top edge of a hip rafter for a tiled roof? Instead of bevelling the top edge state how you could arrange this rafter.

(13) Briefly describe a method of finding by how much one jack rafter is shorter than the one alongside it, and also state how the jack rafters are set out on a common rafter.

(14) Draw a cross section of a roof with a span of 30 ft. and a slope of 30°. Near the centre of the roof there is a bearing partition. Name and show sizes of the various members.

(15) What kind of roof of timber-frame construction would you use over an open building 24 ft. wide?

(16) Describe how you would secure galvanised corrugated iron on a pitched roof. What material would you use for a roof-light or skylight on either side of the roof?

(17) A roof has recently been covered with sheets of corrugated aluminium and the roof surface must be painted. Would you suggest any particular treatment of the roof surface before the paint is applied?

(18) What type of roof covering would you recommend for the flat roof on a house? Describe the methods used to secure the material and provide a finish.

(19) A common rafter for a gable roof has already been set out and you have been instructed to mark the remaining common rafters. Describe how this should be done.

(20) Briefly describe how you would actually set out a hip roof for a rectangular building.

(21) (a) How is a roof pitched?
  (b) Describe a practical method for checking the length of hip rafters.

(22) Fully describe how you would support, tie, and brace members in a roof.

(23) Describe a method of trimming the ends of rafters in preparation for the fascia boards.

Calculations

(1) If one side of a right-angled triangle is 12 ft. long and the hypotenuse is 20 ft. long, what is the length of the other side?

(2) The gable end of a building is in the shape of a triangle with a base of 20 ft. 6 in. and a vertical height of 6 ft. 9 in. What is the area of the triangle in square feet?

(3) A rafter in a gable roof is 13 ft. long and has a rise of 5 ft. Calculate:
  (a) The run of the rafter.
  (b) The pitch of the roof.
  (c) The rise (in inches) per foot run.

(4) (a) The sloping triangular surface at the end of a hip roof measures 32 ft. along the eaves and 12 ft. 6 in. along a line at right angles from the eaves to the apex of the roof. Find the area in square feet of this triangular roof surface.
  (b) A gable roof has a rise of 5 ft. and is 60 ft. long, and the length of the slope of the roof surface is 13 ft. How many square feet of ceiling surface does this roof cover?

(5) The rise of a lean-to roof is 3 ft. 6 in., the span is 12 ft.:
  (a) How many square feet of building paper will be required to cover this roof, which is 20 ft. long?
  (b) What is the cost of this paper if it is bought at 3s. 6d. per square yard?

(6) A hip roof is 50 ft. long, 30 ft. wide; the ridge is 20 ft. and the rise 8 ft. Find:
  (a) Length of the common rafters.
  (b) Length of hip rafters.
  (c) Area of roof.

Chapter 8

EXTERIOR WALL COVERINGS

Various materials are available for sheathing the walls of timber-framed buildings, and the choice of a particular sheathing material is possibly a matter of personal preference in the first instance. Initial and maintenance costs, however, are factors which should be considered.

Common sheathings used in New Zealand are weatherboards, vertical boarding, brick veneer, concrete block veneer, stucco, mineral fibre cement sheets, and sidings.

Weatherboards

Exterior timber sheathing should be of heart quality of the various kinds of timbers but, when such cannot be obtained, sapwood timber may be accepted, provided it has been effectively treated with an approved wood preservative and by an approved process. (See Chapter 3, pages 66–9.)

Weatherboards should be thoroughly seasoned by either air-seasoning or kiln-drying methods to a moisture content of about 17 per cent.

The standard run of weatherboards from sawmills is usually either 6 in. x 1 in. or 8 in. x 1 in., but these dimensions (known as nominal dimensions) are those of the green timber immediately after sawing. After seasoning and dressing the dimensions are reduced in the case of a 6 in. x 1 in. board, to a finished width of about $5\frac{1}{2}$ in., and a thickness of about $\frac{25}{32}$ in. Standard types of weatherboards shown in *Fig.* 266 are available at most timber yards.

Cover and lap of weatherboards

Although a weatherboard may have a finished width of, say, $5\frac{1}{2}$ in., it covers only $4\frac{1}{4}$ in. when it is fixed, because it is overlapped $1\frac{1}{4}$ in. by the board above it; thus each weatherboard actually covers $4\frac{1}{4}$ in. of the height of the wall and laps $1\frac{1}{4}$ in. over the board below it (*Fig.* 267).

As it is not possible to paint the laps of weatherboards after they have been fixed, the boards, or at least the parts in contact, should be painted with priming paint before they are fixed.

Weatherboarding is measured in ft. B.M. It must be remembered that the quantity to be ordered does not refer to the actual cover of the boards when fixed, but to the total area of the individual boards used. The method of calculation for ordering weatherboards, flooring, etc. is given on page 170.

Spacing of weatherboards

The positions of weatherboards are set out on spacing rods so that every board will have an equal amount of cover, i.e. the boards will be evenly spaced.

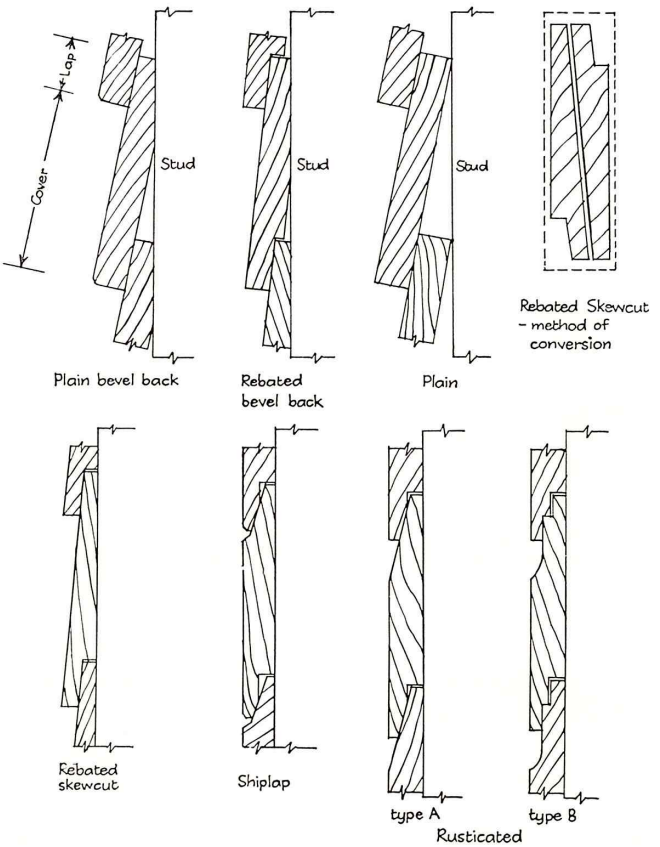


Fig. 266

Types of weatherboards

In most cases the bottom edge of the lowest weatherboard about a building is fixed slightly below the top of the foundation wall and the highest one finished with a scotia against the soffit.

The two common methods of finding the number of boards that are required for a wall are by calculation, and by dividing the height of the wall into equal spaces with wing compasses.

(1) *Example of calculation method*

A wall with a total height of 8 ft. $4\frac{1}{8}$ in. is to be sheathed with weatherboards with a cover of not more than $4\frac{1}{4}$ in. Allowance must be made for a scotia $1\frac{1}{2}$ in. wide at the top of the wall. How many weatherboards are required?

Solution

$$\text{Number of weatherboards} = \frac{\text{total height of wall} - \text{width of scotia}}{\text{cover of a weatherboard}}$$

$$= \frac{8 \text{ ft. } 4\frac{1}{8} \text{ in.} - 1\frac{1}{2} \text{ in.}}{4\frac{1}{4} \text{ in.}} = \frac{8 \text{ ft. } 2\frac{5}{8} \text{ in.}}{4\frac{1}{4} \text{ in.}} = \frac{98 \cdot 625}{4 \cdot 25} = 23 \cdot 2$$

Therefore 24 weatherboards are necessary.

When there are fractional parts in the answer, the next whole number is taken as the number of weatherboards required.

To find the cover of each weatherboard the height of the wall is divided by the number of weatherboards.

$$\text{Cover of each weatherboard} = \frac{\text{height of wall} - \text{width of scotia}}{\text{number of weatherboards}}$$

$$= \frac{98 \cdot 625}{24} = 4 \cdot 109 \text{ or } 4\frac{1}{8} \text{ in. bare}$$

(2) *Using wing compasses*

The height of the wall is taken on a rod and the width of the scotia deducted before the remaining distance is stepped out with wing compasses set to the cover of a weatherboard. Should the last step be less than $4\frac{1}{4}$ in. the points of the compasses are closed slightly and the process repeated until the distance is equally spaced.

Spacing rods (*Fig.* 268)

Spacing or guide rods for evenly spacing weatherboards are made with a head-piece in the shape of a capital letter T, and hang from the top plate on the outside of the wall. A rod is marked with horizontal lines that coincide with the lower edges of weatherboards, and these marks are made permanent with a saw cut exactly over each mark. The original rod is used as a pattern for marking as many others as are required for the job.

Note: Carpenters often prefer to set out a spacing rod to the top *edges of weatherboards and so avoid having the nail holes of guide nails on the faces of the boards.*

Use of spacing rods (*Fig.* 269)

A spacing rod is hung at each end of a wall being weatherboarded and on long walls another rod is used at intermediate positions. Alongside the lowest mark on each spacing rod a nail is partly driven, thus forming a row of nails upon which a weatherboard is rested while it is being fitted, straightened, and secured. These partly driven nails are known as temporary bearing or guide nails. After the first weather board has been secured, the next row of guide nails is placed for the next weatherboard. The guide nails are withdrawn when their purpose has been served.

Spacing rods serve as a gauge for the correct spacing of weatherboards as well as for keeping them horizontal.

Use of spacing rods and line

Instead of using intermediate spacing rods, a line may be stretched between the bearing nails at the ends of a wall. The centre of the line is raised slightly to allow for any sag, and after being sighted for straightness,

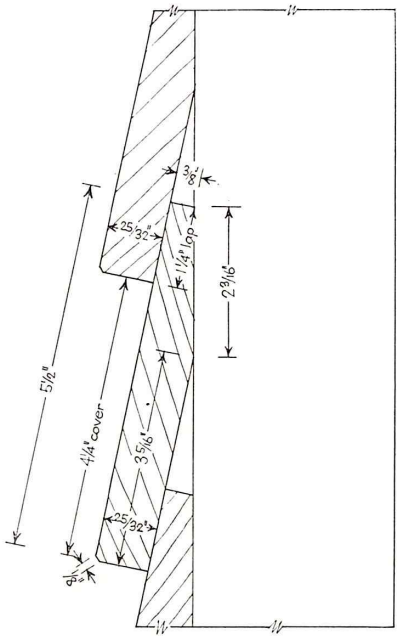


Fig. 267

Cross section of bevel-back weatherboards

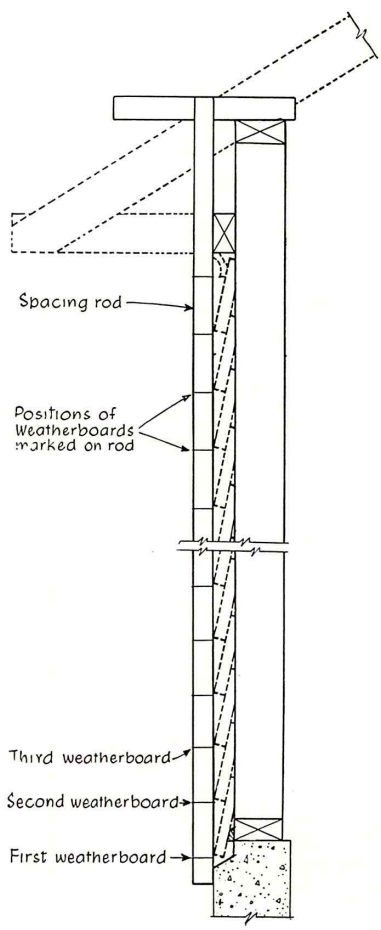


Fig. 268

Spacing rod hanging on wall

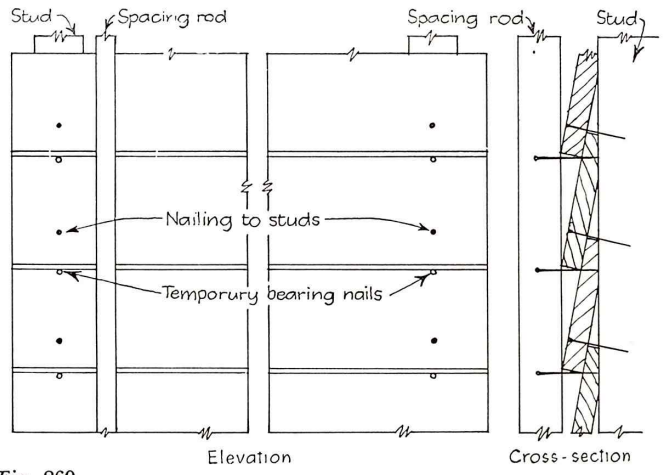


Fig. 269

Position of bearing nails

bearing nails are placed under the line at any desired position. This process is repeated for every weatherboard.

On a short wall broken by openings it is often an advantage to use a straight edge instead of a line. In some cases the positions of intermediate bearing nails can be determined by sighting, or by using a gauge block (*Fig.* 270).

Finish at corners and openings

Before weatherboards are sawn to length one must know how the corners of the building are to be finished and also the kind of finish to be adopted at window and door openings.

Various finishes and allowances on the lengths of weatherboards are as follows:

(1) *External corners*

(a) Weatherboards mitred. (An additional length of at least $1\frac{1}{2}$ in. is allowed for the cutting of each mitre.)

(b) Angle boxes covering corners. (Boards are sawn to exact lengths or left slightly long to project over openings and are sawn to their proper lengths after they have been fixed.)

(c) Butted against angle stops. (Boards should be of sufficient length to allow a square cut to be made at one or both ends of the boards.)

Note: Angle stops are not used to any extent on residential work.

(2) *Internal corners*

The ends of the weatherboards are scribed and fitted to the boards on the adjacent wall. (An additional length of about 3 in. is allowed for fitting.)

(3) *Door and window openings*

(a) Butted against door and window jambs. (Length should be sufficient to allow for making a square cut at one or both ends.)

(b) Openings trimmed with facings. (Boards are sawn to exact lengths or allowed to run past an opening and later sawn to proper length when they have been fixed.)

Selection and sawing weatherboards to length

It is good practice to mark a rod with the lengths of each wall to be weatherboarded, allowing extra length for mitres if necessary, and along each mark place the number of boards required for the particular section. The rod is then taken to the timber stack where the weatherboards are sorted into the various lengths required. Crooked boards are cut into the shortest pieces required or, if too warped, they are discarded.

When arranging weatherboards for cutting into various lengths make certain that the longer ones are cut into shorter lengths with the least amount of waste. One method of arranging the boards is to place the longest ones in a convenient sized stack, and after mark-

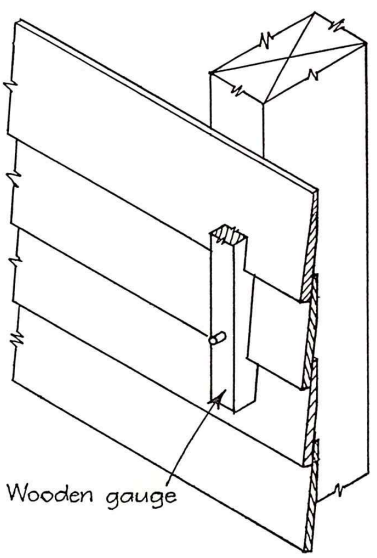


Fig. 270

Gauge block

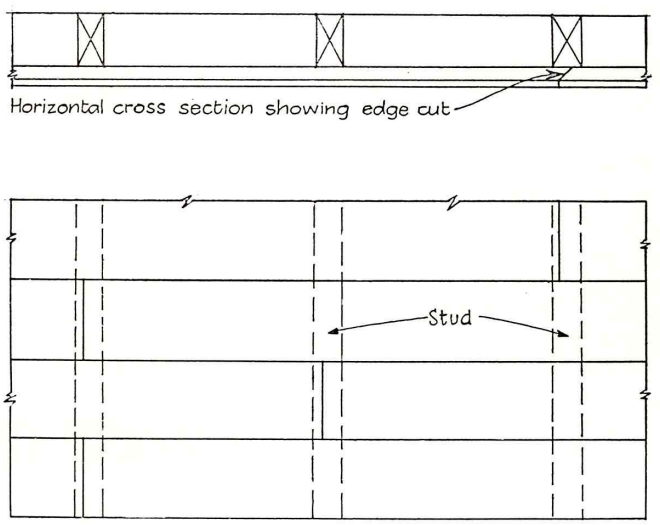


Fig. 271

Lengthening joints

ing out the top board into as many of the same or different lengths as required, lines are squared across the top board and down one side of the stack. The stack is then sawn through at each place marked, after which the weatherboards are stacked near to where they will eventually be used.

Jointing of weatherboards

(a) *Lengthening* (*Fig.* 271)

Weatherboards are lengthened with a splayed joint. The ends of boards are cut at an angle of 45° on edge and square across the face.

Splayed joints should be scattered as widely apart as possible.

(b) *Exterior angles* (*Fig.* 272)

On an exterior angle weatherboards are frequently mitred.

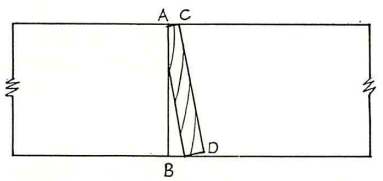


Fig. 272

Method of finding face cut of mitred weatherboard

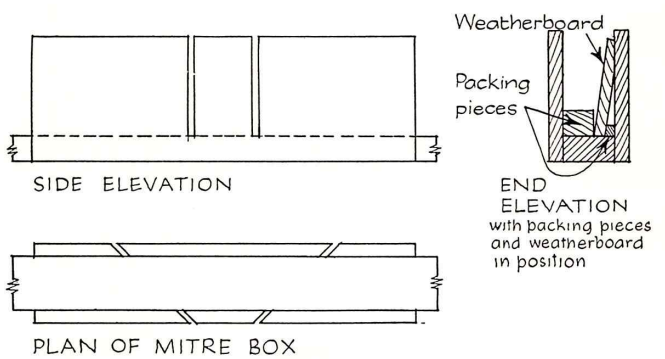


Fig. 273

Mitre box and arrangement of a weatherboard for sawing mitres

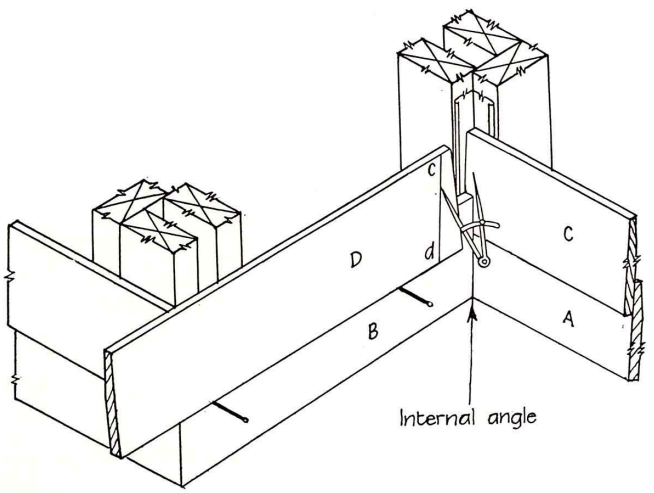


Fig. 274

Scribing weatherboards

The bevels for this joint may be developed in a similar way to roof cuts, but, on the actual job, a line AB (*Fig.* 272) is squared across the board and a square end section of a weatherboard scribed against AB. A bevel is set to the line CD which is the face cut. The edge cut is slightly more than 45°.

Often carpenters make a template for the face and edge cuts, to which the mitres are marked and sawn.

A practical method of obtaining the correct bevels for a mitre cut is to place a packing piece in a mitre box so that the weatherboard being sawn is tilted to the same slope as it will be against the studs (*Fig.* 273).

Interior angles

In an interior angle weatherboards are scribed, the end of one board being fitted against the face of another on the adjacent wall (*Fig.* 274).

Board A is first secured and board B is scribed to it.

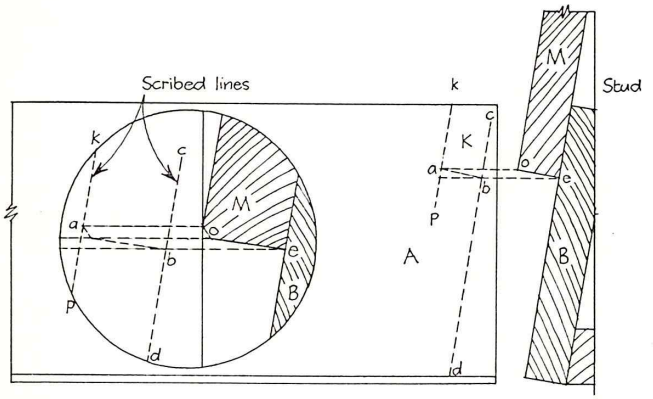


Fig. 275

Method of scribing

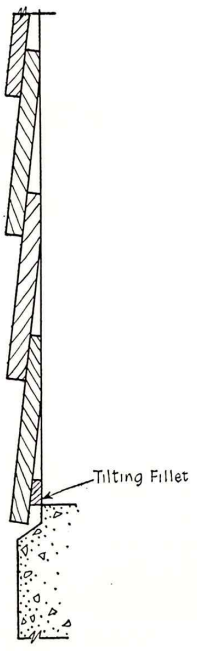


Fig. 276

Fitting tilting fillet

Board C is notched at the bottom to fit over board B. Board D is placed on the temporary bearing nails and, with wing compasses open to any convenient distance, scribe the line cd to the slope of the board C. Any irregularities in this line are followed when sawing.

When one adjacent wall has already been boarded as shown in *Fig.* 275, a notch marked K must be sawn out so that the board A will fit to the bottom edge of the board M. After scribing the line cd on A, with the same compass setting scribe the line kp from the face of the board M.

To obtain the oblique line ab which coincides with the bottom edge of the board M, from o and e draw horizontal lines cutting kp and cd at points a and b. Join ab. Saw accurately to the lines.

Some weatherboards have a bevelled lower front edge, as shown in enlarged part in *Fig.* 275. A narrow chisel should be used to make the corresponding cut on the board being fitted. A metal flashing should always be fitted behind the weatherboards at an internal corner.

Lowest weatherboard (Tilting fillet, *Fig.* 276)

There are two matters to be considered before the first or lowest weatherboard is secured to the framing.

(1) As this board is not supported by another below it, packings known as tilting pieces are nailed either to the back of this board or to the framing, so that its front edge will line up with the others on the wall.

(2) The lower edge must be about $1\frac{1}{2}$ in. or 2 in. below the top of the concrete base wall to prevent water soaking into the joint between the framing and the concrete wall (*Fig.* 276). Note that the lower edge of the board does not touch the wall. There are various methods of making a neat finish between the lowest weatherboard and the concrete wall.

Straightening a board

The lower edges of weatherboards must be as straight as possible before the boards are secured. Straightening a long board is preferably done by two carpenters. One sights along the edge while the other corrects any irregularities of line by levering the top edge downwards or the bottom edge upwards as circumstances demand and then nailing the board when the edge is straight. This process may have to be done at several positions before the edge is perfectly straight.

Nailing

Ordinary $2\frac{1}{2}$ in. or 3 in. rose-head nails are used to secure weatherboards at each stud. The nails are placed about $1\frac{3}{8}$ in. from the lower edges of boards so that they just clear the top edge of the board immediately below. If the nails are driven through the top edge of the lower board there is a possibility that part of this edge will split off during shrinkage and so lessen the amount of lap. Nail heads are driven below the surface of the boards with a nail punch.

Ordinary bright-steel nails may be used in most cases, but when fixing weatherboards of redwood, totara, or cedar, zinc-coated nails should be used because a substance in these timbers has the effect of corroding ferric metals.

Sheathing of framing with building paper (*Fig.* 277)

The exterior walls of a timber-framed building that is to be used for human habitation should be sheathed with building paper or similar materials before the weatherboards are secured. The building paper provides a moisture and draught-proof barrier in the walls.

Building papers are generally made of either waterproofed paper or felt impregnated with bitumen. A popular building paper comprises two layers of paper cemented together with bitumen and reinforced with unspun sisal fibres. Building papers are available in rolls of varying widths, but the 3 ft. wide rolls are popular because they are easily handled. The paper is lapped 2 in. at horizontal and 6 in. at vertical joints and corners, the paper being secured to the framing with $\frac{1}{2}$ in. or $\frac{3}{4}$ in. large-headed galvanised clouts at about 12 in. centres. Instead of securing the building paper with clouts, it may be temporarily held with battens until the sheathing has been fixed.

Methods of weatherboarding

A description will first be given of the usual methods of weatherboarding, without consideration of how the

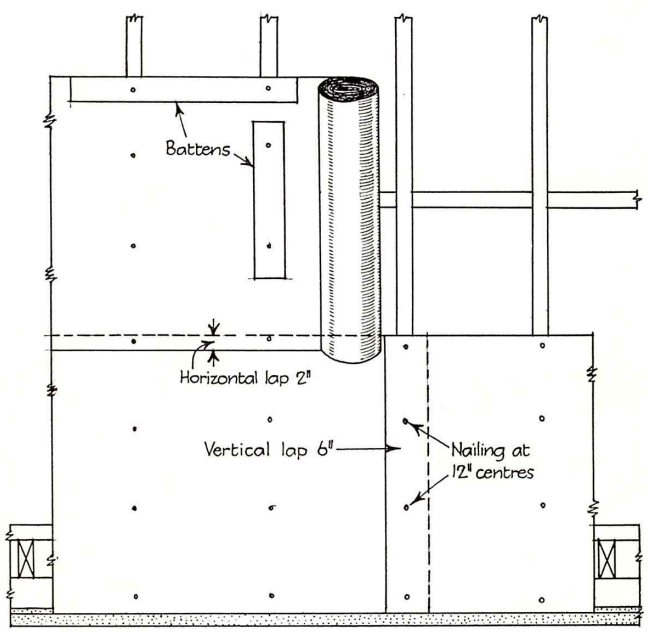


Fig. 277

Methods of securing building paper

weatherboards are to be finished at the corners, and following this, slightly different procedures will be outlined for various corner finishes.

(a) *Weatherboarding walls*

The procedure is as follows:

(1) A tilting fillet is nailed on the back of the lowest weatherboard or on the framing.

(2) Bearing or guide nails are partly driven alongside the lowest position on the spacing rods. Frequently these nails cannot be driven on account of the concrete foundation wall and consequently a row of guide nails must be driven to coincide with the top edge of this board.

(3) The lowest weatherboard is placed in position, sighted along the lower edge for straightness, and then secured.

(4) Bearing nails for the second board are driven alongside the particular mark on the spacing rods, and the board placed in position, after which it is straightened and then secured.

(5) The remaining weatherboards to the top of the wall are fixed in the manner described for the second weatherboard.

(6) The lengthening joints for weatherboards should be splay jointed with the joints scattered as widely apart as possible. Such joints should be painted before being secured.

(b) *Angle boxes*

When angle boxes are used for covering external corners and facings for trimming window and door openings, the weatherboards are not always sawn to exact lengths but are slightly longer than necessary and are fixed with the waste ends projecting over openings. Those weatherboards alongside the top of an opening must be sawn to an exact length to provide a space for the saw to be started when cutting the boards to their correct length.

When all the weatherboards have been fitted, the angle boxes are secured.

(c) *Angle stops*

The ends of weatherboards are butted against angle stops and a design often demands the same kind of finish against the jambs of window and door openings. In such circumstances the angle stops and also the window and door joinery must be in place before weatherboarding is commenced. Standard practice is adopted when fixing the weatherboards. The ends of boards against the stops and jambs are cut square and painted before being placed tightly in position against the flashing of the angle stops and jambs (*Fig.* 323).

(d) *Mitred corners*

When weatherboards are to be mitred on the external corners of a building either of the following methods could be adopted:

(1) Making a mitre cut on the ends of weatherboards before each board is fixed.

A mitre cut is made on the end of a board. The board is secured after its opposite end has been marked to length and the appropriate cut made. In this manner all the weatherboards on one wall are fitted and secured. The next wall is then done similarly, and so on around the job.

A mitre that has been accurately sawn should require little if any adjustment, but if such is necessary it is made by running a fine saw in the joint or by removing the boards and planing the fitting edges. These edges should be coated with paint before the boards are secured.

(2) Sawing mitres on weatherboards after fixing.

To enable a mitre to be sawn on the ends of weatherboards already fixed on a wall a corner stud is arranged so that it may be temporarily removed during sawing operations. On account of obstructions below floor level and also in proximity to the roof, the weatherboards in these parts must be mitred and fixed board by board.

If we assume that a rectangular building is to be weatherboarded we would first weatherboard the long walls in the usual manner and would allow the weatherboards to extend past the external corners a sufficient distance for the mitres to be cut. A mitre is set out on the lowest and highest boards and the long points of each mitre connected by a straight edge nailed on the wall to serve as a guide when sawing with either a power or hand saw. The ends of weatherboards on the short walls are each sawn to a mitre cut before being fixed board by board.

(e) *Use of soakers*

Mitres of weatherboards are sometimes covered with copper flashings known as soakers (*Fig.* 278). A soaker

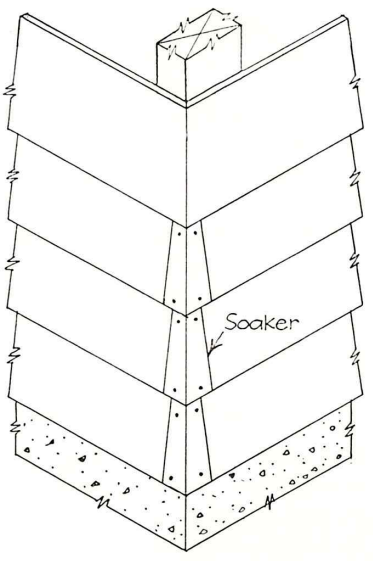


Fig. 278

Mitred weatherboards and soakers

not only protects a corner but also covers an open joint which may have resulted from shrinkage. Soakers have the disadvantage that they are of metal and are inclined to move with changes of temperature and thus allow water to be drawn under their edges by capillarity. The very sharp points of soakers, fixed at low levels, may be a potential danger to persons passing by.

Weatherboarding of gable ends

Before the weatherboarding of a gable end is commenced, the eaves soffit linings over the gable should have already been fixed. Assuming that the walls of the building have been weatherboarded to the level of the soffit, on the side walls, this leaves a triangular shape to be weatherboarded. The length of the base of the triangle is measured with a steel tape or by resting two light rods on the bearing nails, and extending them until their ends reach the soffit on either side of the gable. The angle of the slope of the roof is obtained by placing a board against the gable soffit and marking the slope of the roof across the topmost weatherboard. A bevel is set to this slope. Having found the length and end cuts of the first gable weatherboard, it is sawn to shape but not fixed in the meantime, for it is used as a pattern for marking the next weatherboard above it. From the bottom edge, a line is gauged, to the amount of cover, and as many bearing nails as required are partly driven to the line. The next board is laid against the bearing nails, and, after its length has been derived from the lower board, the roof slope is marked. The first board may now be fixed on the wall while the second one is being used as a pattern for marking the third one, and, in this way, the rest of the boards are first marked for length and then sawn to shape. By this method the weatherboards for the gable may be all marked and cut before fixing, or the work handled by one carpenter marking and shaping the boards while another fixes them.

Bell-cast finish (*Fig.* 279)

A bell cast is formed when the lower portion of the surface of a wall is curved outwards in the shape of a bell. The purpose of a bell cast is to break the straight line of a wall or to provide a suitable junction between two different building materials. It is constructed at the junction of storeys, in gables, and under windows.

A bell cast is framed by fixing pieces of timber, curved to the shape of the outside of a bell, on the framing where the bell cast is to be formed. The weatherboard or other sheathing on the wall covers this framing in the usual way.

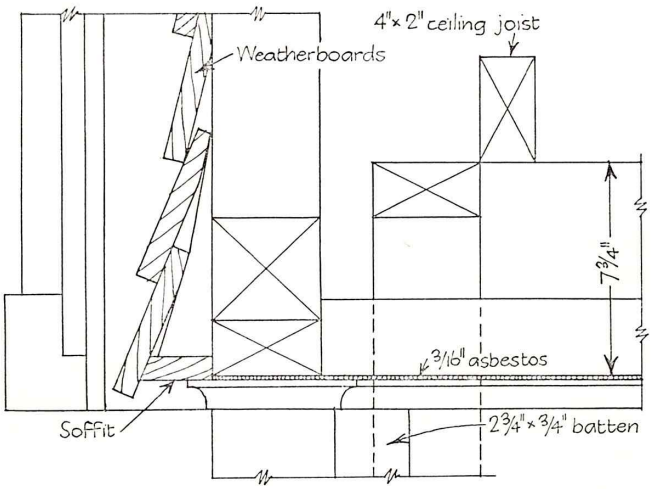


Fig. 279

Bell-cast finish for gable (cross section through entrance porch)

Vertical boards and battens (*Fig.* 280)

Of recent years sheathings of vertical boards and cover battens have been adopted to an increased extent for dwellings, but in the past only porches have been sheathed with such materials.

Vertical boards vary from 6 in. to 9 in. in width and the battens that cover the joints are about $2\frac{1}{2}$ in. x $\frac{3}{4}$ in. The individual boards are placed $\frac{1}{4}$ in. apart and have weather grooves within $\frac{1}{2}$ in. of each edge over which a double-grooved batten is fixed. The edges of boards are prevented from splitting, as a result of the effects of shrinkage, by nailing the battens between the boards or to one board only.

Mineral fibre cement sidings (*Fig.* 281)

Mineral fibre cement sidings are flat rectangular pieces of mineral fibre cement board about 24 in. long by 12 in. wide and $\frac{3}{16}$ in. thick. They have an imitation cedar-grained surface on the side to be exposed and either a wavy or straight lower edge. Sidings are already punched with holes for nails.

Sidings are secured to either 2 in. or 3 in. x 1 in. battens fixed horizontally on the framing at $5\frac{1}{4}$ in. centres up to 7 ft. above ground level, and above this at $10\frac{1}{2}$ in. centres. The purpose of the closer battening at the lower levels is to provide additional protection against damage. The bottom edges of the lowest sidings on a wall are tilted by having the lowest batten wedged out or sawn to a splayed shape.

Before the sidings are fixed the walls are covered with a damp-proof barrier of bituminous felt secured hori-

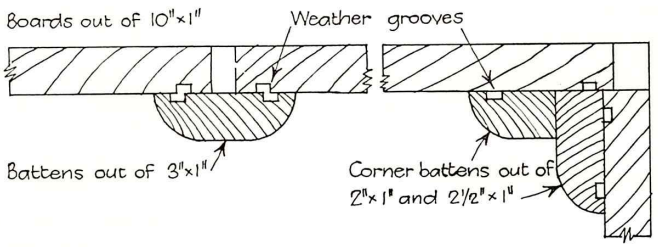


Fig. 280

Cross section of vertical boards and battens

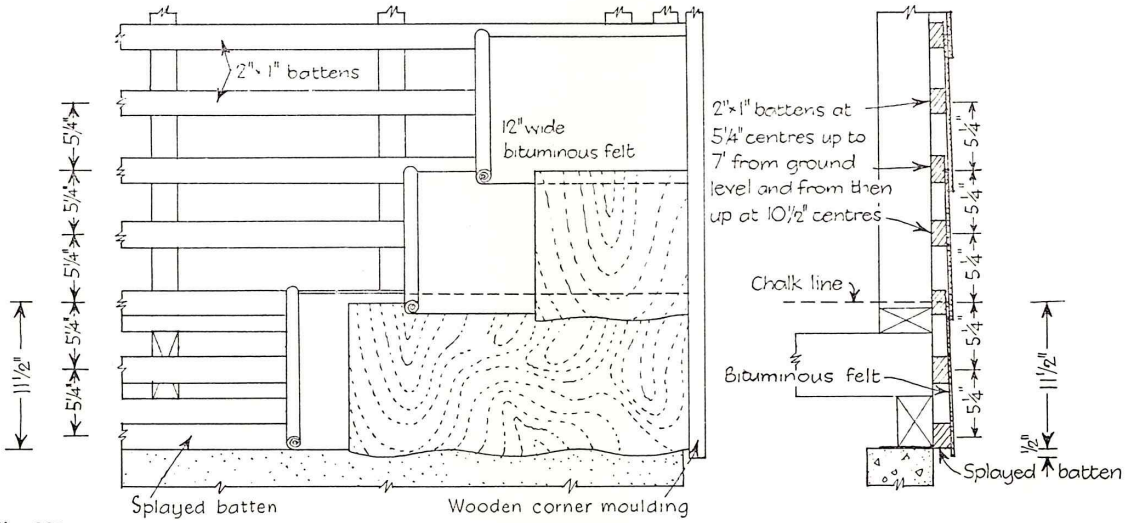


Fig. 281

Fixing of mineral fibre cement sidings

zontally in widths of either 12 in. or 36 in. The felt is lapped at joints and secured with galvanised clouts.

Fixing of sidings

The sidings are fixed with $1\frac{1}{4}$ in. x 14 S.W.G. flat-head galvanised nails.

The first course of sidings must be level and straight. Measure $11\frac{1}{2}$ in. up from the bottom edge of the bottom batten and run a chalk line along the third batten at this level (*Fig.* 281).

Keep the upper edge of the sidings to this chalk line, and drive nails through each of the holes already punched in each siding.

The second course of sidings is commenced with a half width siding to break the joint. The correct alignment of the second and succeeding courses will be maintained if the lower line of nails just grazes the top edges of the row of sidings below.

External angles (*Fig.* 282)

A specially shaped corner beading either of wood or metal is used at external angles and the short edges of the sidings are kept tight against it.

Internal angles (*Fig.* 283)

Internal angles should be flashed with either a metal or bituminous fabric angle flashing. So that one siding will fit tightly against another, the cut edges of sidings should be smoothed with a file.

Sheathing of walls with mineral fibre cement sheets

Mineral fibre cement sheets are made of clean asbestos fibre bound together with Portland cement. A uniform colour is obtained by adding a colouring substance. The sheets have a smooth surface on one side and are comparatively rough on the other, the smooth surface being exposed to the weather. Standard sizes of sheet range in length from 6 ft. to 10 ft., and in width from 3 ft. to 4 ft., with a thickness of $\frac{3}{16}$ in., $\frac{1}{4}$ in. and $\frac{3}{8}$ in.

A guillotine hand tool is used for cutting sheets to shape, or the corner of a file is used to score a groove along which the sheet is broken (*Fig.* 284). Sheets may also be sawn with an old hand saw reserved for this work.

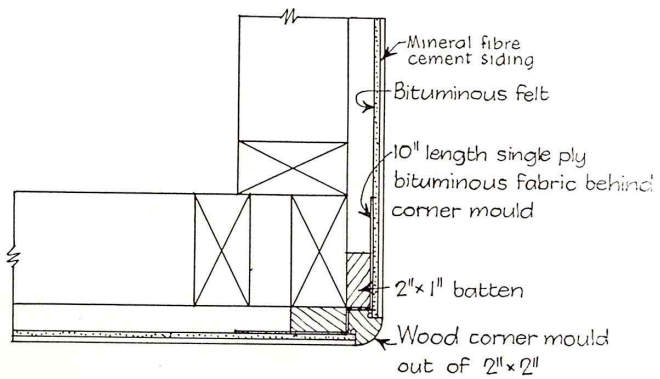

Mineral fibre cement siding
Bituminous felt
10" length single ply bituminous fabric behind corner mould
2"×1" batten
Wood corner mould out of 2"×2"

Fig. 282

Cross section of external corner

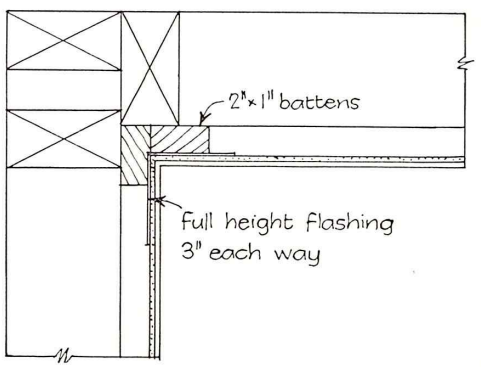


Fig. 283

Cross section of internal corner

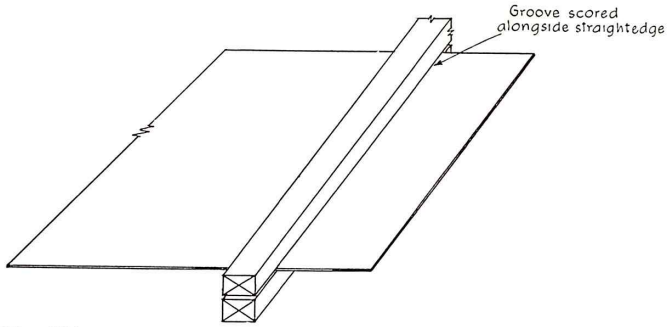


Fig. 284
One method of cutting mineral fibre cement sheet

Clout nails

Galvanised flat-head clout nails that have a blunt point are used for securing the $\frac{3}{16}$ in. sheets. A blunt-pointed clout is preferred because it breaks its way through, taking a small part of the sheet with it, whereas a sharp-pointed clout will spread the surrounding material, with the result that, when nailing near the edges, a part of the sheet will break away. The heads of clouts are driven only far enough to hold the sheet, because, if the heads are made flush, they tend to break a hole through the sheet. The clouts should be at least 1 in. long, spaced at about 9 in. centres over the sheet and within $\frac{3}{8}$ in. of the edges.

Joints of sheets (*Figs.* 285, 286, 287)

Joints of sheets are covered with either mineral fibre cement or wooden mouldings. Horizontal joints covered with plain D mouldings are flashed with sheet metal (*Fig.* 285). A special horizontal mineral fibre cement moulding requires the dwangs to be set back for the top edge of the moulding, the studs housed to a depth of $\frac{5}{16}$ in., and a $\frac{5}{16}$ in. packing piece fixed to the dwang to support the top edge of the lower sheet (*Fig.* 286). The edges of the sheets above the moulding are seated in a bituminous compound.

Vertical joints have either a strip of bituminous fabric under them or they are sealed with a bituminous compound. Mouldings are usually of the flat D type, the vertical ones being either scribed as in *Fig.* 285, or mitred into the horizontal moulding. Corners are made weatherproof with angle boxes of wood, or specially made angle covers of mineral fibre cement. Types of mouldings are shown in *Fig.* 287.

Framing for mineral fibre cement sheets

Framing for mineral fibre cement sheets should be of solid construction to prevent, if possible, any subsequent movement of the timbers, which would tend to crack the sheets. Studs are spaced at from 18 in. to 2 ft. centres, depending upon the type of building and to suit the width of the sheets. The edges of sheets must have a solid bearing of at least 1 in. on studs. Dwangs are fixed at about 27 in. centres to provide bearing and solid

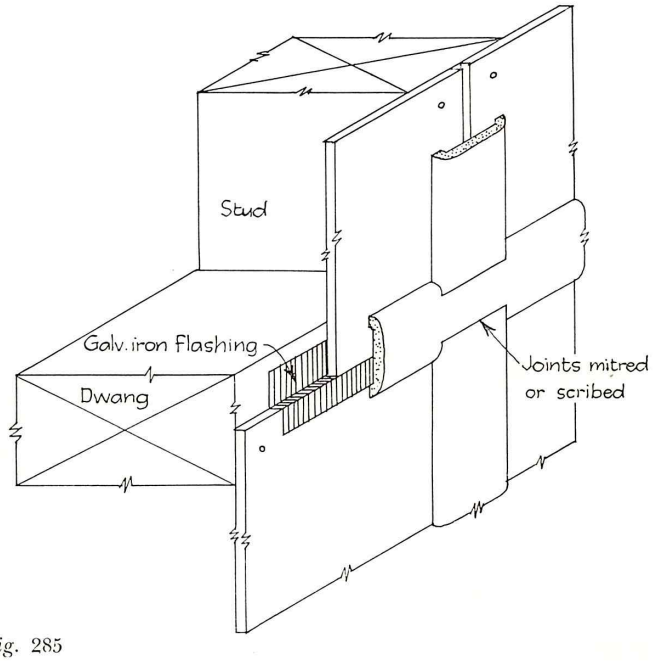


Fig. 285
Joints and battening of mineral fibre cement sheets

nailing along all the edges. On account of the brittle nature of mineral fibre cement sheets, walls are often sheathed with thin boarding before these sheets are fixed.

Brick veneer

A brick veneer house has an outer wall of bricks around a wooden frame, the brickwork being tied to the framing across a cavity. The bricks are laid in stretcher bond (*Fig.* 288).

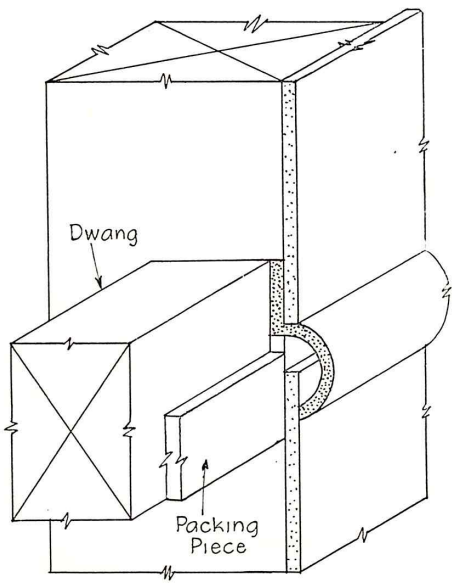


Fig. 286
Special horizontal moulding

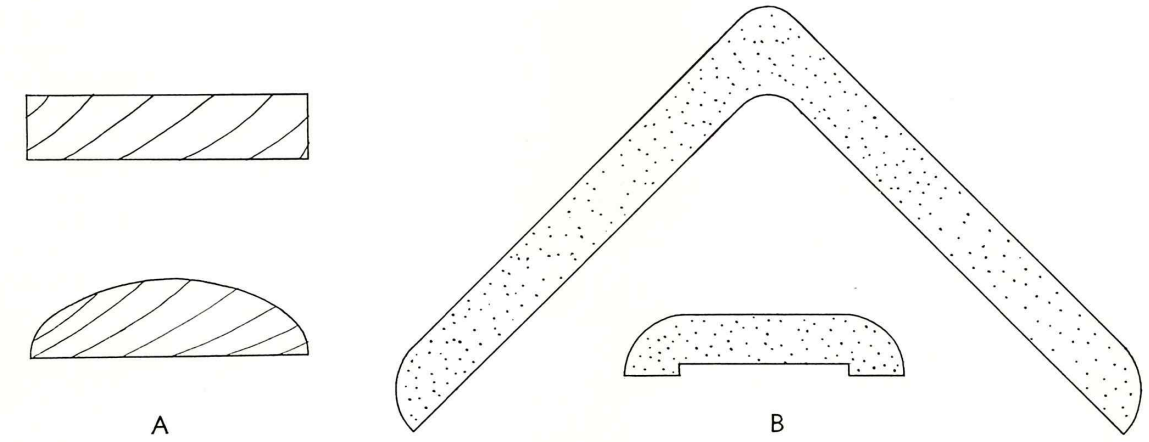


Fig. 287

Cover mouldings

(A) *Cross section of wooden mouldings* (B) *Cross section of mineral fibre cement mouldings*

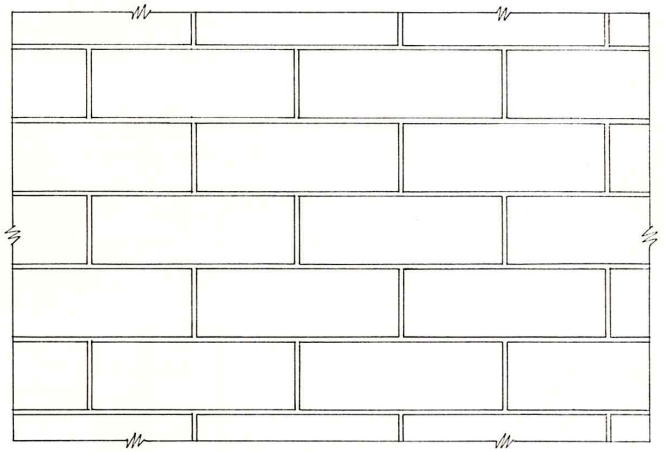


Fig. 288

Bricks laid in stretcher board

Bricks

The bricks are common or facing bricks, hard, sound, well burned, and of a uniform size and colour. Joints for brickwork should not exceed $\frac{3}{8}$ in. in thickness and are weather-struck (*Fig.* 289). When the brickwork is to be colour washed or cement painted, the joints are frequently made flush.

Proportions of mortar for brickwork

Mortar for brickwork is composed of:
(a) One part cement to three parts sand; or
(b) One part cement and 1 part lime to five or six parts sand.
In general the proportions are about one volume of cementing material to three volumes of sand.

Cement mortar

Ordinary Portland cement or rapid hardening Portland cement is used for mortars. The cement should be fresh and the mortar mixed in relatively small quantities as the setting action commences directly water is added.

Cement–lime mortar

When making a lime-cement mortar the lime is well mixed with the sand and water and allowed to stand for at least forty-eight hours before being used. The required proportion of cement is mixed in just before use and further water added if necessary. In general the presence of cement in a mortar ensures that it will have high early strength. The addition of lime improves the working qualities of the mortar and reduces its tendency to shrink and crack on drying.

Hydrated lime is a kind of lime that may be mixed with sand and water and used immediately but the working qualities of the mix are improved if it is allowed to stand for forty-eight hours.

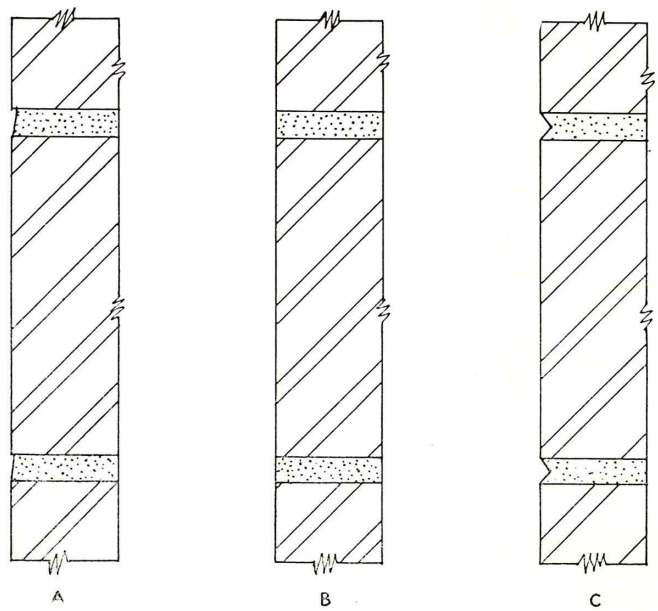


Fig. 289

Types of joints

(A) *Weathered joint* (B) *Flush joint* (C) *Vee joint*

Sand

Natural sands that will pass a $\frac{3}{16}$ in. sieve form the usual aggregate for mortar. The use of clean, sharp sand is essential.

Water

Water used for mixing mortar should be clean and free from impurities (e.g., salt or foreign matter). The presence of salt in solution may cause subsequent efflorescence on the face of the brickwork.

Foundations for brick veneer

As brick-veneer walls are much heavier than other types of sheathing the foundation walls must have a footing to take the extra weight (*Fig.* 290).

Thickness and height of veneer walls

Brick-veneer walls are $4\frac{1}{2}$ in. wide. As a brick-veneer wall cannot be higher than 12 ft. above the top of the foundations (N.Z.S.S. 1900, Chapter 6.1) the upper portions of buildings higher than this must be sheathed with material other than brick veneer. In single-storey buildings the brick veneer is finished under the eaves soffit, and in two-storey work a convenient place to finish would be at the windowsill level of the upper storey (*Fig.* 291). *Fig.* 292 shows the methods usually adopted to strengthen the walls in two-storey work.

Wall ties (*Fig.* 293)

A brick-veneer wall is secured to the timber framing with wire ties made of No. 8 S.W.G. wire formed into the general shape and measurement shown in *Fig.* 293. The tie is galvanised after fabrication. It is twisted into such a shape that one end can be embedded in a joint of the brickwork and the other secured to a stud. Ties are built in at 3 ft. centres horizontally in every fourth course of brickwork and additional ties are built in opposite cross walls, at angles, and around openings. Ties must be staggered. N.Z.S.S. 1900, Chapter 6.1, provides that at least two ties must be provided to each square yard of brickwork. The purpose or having a twist in a wire tie and also of fixing it on a slope is to deflect into the cavity or against the brickwork any water which would tend to flow from the brickwork to the timber framework.

Reinforcing metal bonding

Horizontal metal bonding should be used to increase the strength of a wall at approximately 3 ft. vertical intervals. This galvanised bonding mesh is obtained in strips about $3\frac{1}{2}$ in. wide and is placed in the appropriate joints between the bricks. Joints in the wire mesh are lapped $1\frac{1}{2}$ in.

Cavity between brickwork and timber framing

As a $4\frac{1}{2}$ in. brick wall will not keep out dampness, because both the bricks and the mortar joints between them are not entirely waterproof, a cavity of not less than $1\frac{1}{2}$ in. must be provided between the brickwork and the timber framing.

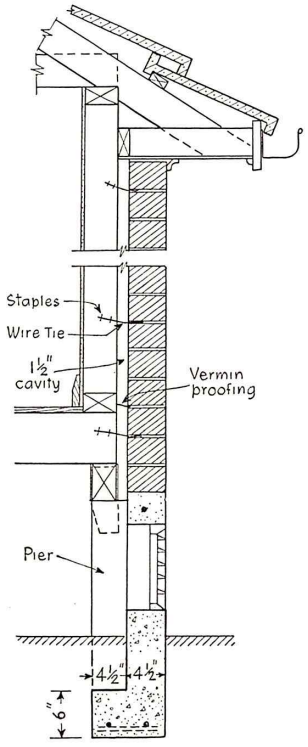


Fig. 290

Typical brick-veneer wall on reinforced concrete foundation

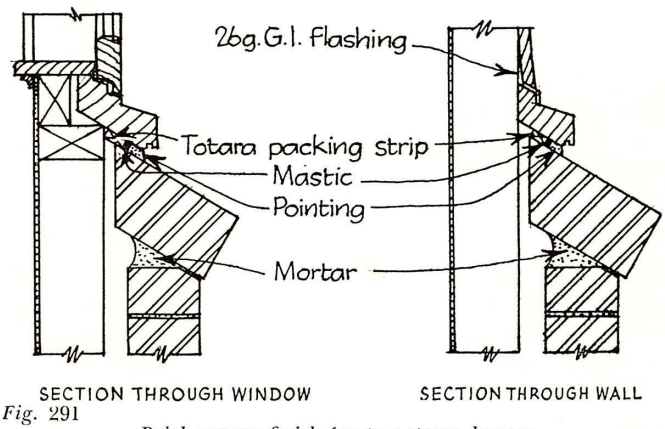


Fig. 291

Brick-veneer finish for two-storey houses

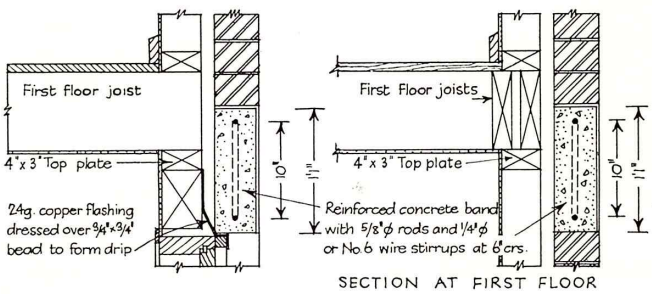

First floor joist
4"x3" Top plate
24g. copper flashing dressed over ¾"x¾" bead to form drip
10"
11½"
First floor joists
4"x3" Top plate
Reinforced concrete band with 5/8"ϕ rods and 1/4"ϕ or No.6 wire stirrups at 6" crs.
10"
11½"
SECTION AT FIRST FLOOR

Fig. 292

Strengthening band of reinforced concrete in two-storey brick-veneer work

Ventilation

Adequate ventilation is most essential in brick veneer so that air currents will dry out any moisture which may otherwise tend to collect behind the brickwork. This drying out of the timber will prevent the setting up of timber rot. It is therefore essential that an adequate number of ventilation openings should be placed in the foundation walls of the building so that currents of air may circulate behind the brickwork and evaporate any moisture.

Vermin proofing the cavity (*Fig.* 294)

Rats and mice are excluded from the cavity between the walls by means by 4 in. wide strips of fine gauge galvanised wire netting placed across the cavity at bottom plate level. The netting is secured to the plate with galvanised wire staples and incorporated in a joint of the brickwork below the level of the bottom plate. The netting is sloped towards the brickwork to deflect from the building any droplets of water that may collect on the wire mesh.

Mortar droppings in cavity

When erecting a brick-veneer wall a bricklayer takes the precaution of preventing the accumulation of mortar droppings on the wire mesh vermin proofing and on the wire ties. It is obvious that an undue amount of mortar on the wire mesh would restrict the ventilation of the cavity and also, together with mortar on the wire ties, would tend to transfer moisture from the brickwork to the framing.

Forming lintels (*Fig.* 295)

There are various methods of forming lintels in brick-veneer walls. In single-storey work the tops of the windows are frequently arranged under the eaves soffit and consequently a lintel is not required over such openings. In other circumstances the brickwork is supported either by a reinforced-concrete lintel or a galvanised angle iron over the opening. It is important that any metal support is either galvanised or zinc sprayed to resist corrosion. The size of the angle iron depends on the span and weight of the brickwork above it.

Sills

Windowsills are formed of concrete or bricks placed on edge. The joint between the wooden sill and the bricks or concrete is made watertight with a bituminous compound.

Door and window frames

In brick-veneer walls the frames are placed into position before the brickwork. Heart totara or other durable timber fillets are secured on the outsides of the frames, and serve as a backing for the bricks about an opening and also for the mastic and mortar in the joints between the frame and the bricks.

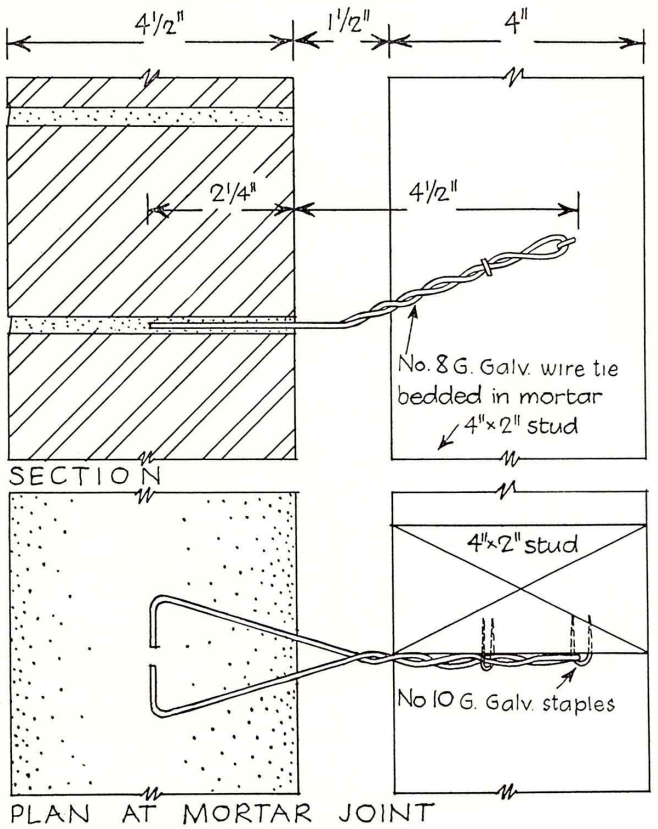


Fig. 293

Wall ties in brick veneer

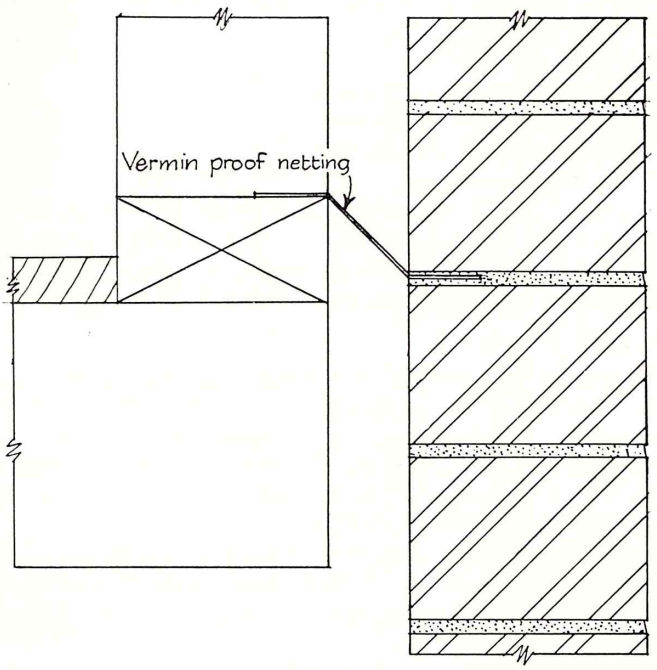


Fig. 294

Method of vermin-proofing brick veneer

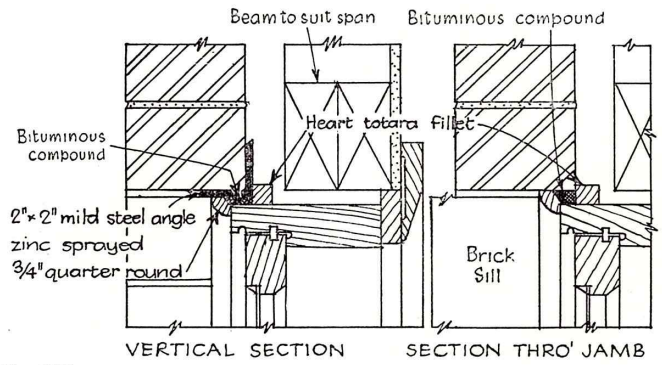


Fig. 295
A method of supporting a brick lintel and weatherproofing joinery

Gable ends

Gable ends of buildings, sheathed with brick veneer, are usually finished with materials other than brick veneer on account of the restriction on the height of veneer walls.

Stucco on timber-frame buildings

Stucco is a general term for plastered surfaces, but especially applied to cement surfaces to imitate stone. When the exterior walls of timber-framed buildings are intended to have an exterior covering of stucco, such walls must have continuous concrete foundations. The framing is covered with either rigid or non-rigid backing materials of various kinds which form a base over which reinforcing wire mesh is stretched before the cement mortar is applied to the surface.

The following materials may be used as a backing for stucco:

(1) *Rigid backing*
(a) Precast cement wallboards.
(b) Mineral fibre cement sheets.
(c) Timber sheathing close boarded.

(2) *Non-rigid backing*
Either a waterproofed building paper or felt impregnated with bitumen or some other suitable materials. The building paper should have a weight of not less than 10 lb. per 100 sq. ft. See N.Z.S.S. 1900, Chapter 6.1.

General procedure

The framing must be protected from dampness and consequently a damp-proof barrier of building paper or similar materials must be arranged over the backing (see N.Z.S.S. 1900, Chapter 6.1). When a building paper is used as a backing it serves the combined purpose of a backing and a damp-proof barrier.

Stucco should be reinforced with the following:
(1) Metal lath or galvanised wire mesh not greater than 2 in. mesh or less than 16 S.W.G. and 1·05 lb. per square yard.
(2) Galvanised wire netting not greater than $\frac{3}{4}$ in. mesh or less than 19 S.W.G. and 1·59 lb. per square yard.

Reinforcing must be stretched taut and fixed not less than $\frac{1}{4}$ in. or more than $\frac{3}{8}$ in. clear of the backing material, by use of special furring nails or other metal devices.

Joints in reinforcing should be lapped at least one mesh and joints at angles are not allowed. On each side of all angles the reinforcing should be doubled for 1 ft., and on all corners of openings extra 18 in. x 12 in. pieces should be fixed diagonally across the corners (*Fig.* 296).

Galvanised fixing nails should be spaced at not more than 6 in. centres along all studs and dwangs. Laps should be lashed with 20 S.W.G. galvanised-iron wire or connected by clips.

A description will now be given of the various materials and practices adopted for the preparation of wall surfaces for stucco.

Rigid backing of cement sheathing boards (*Figs.* 296, 297)

There are many kinds of cement boards that may be used as a rigid backing on timber-framed buildings. One of the more common kinds has dimensions of 4 ft. 6 in. x 3 ft. x $\frac{3}{4}$ in.

The cement boards are usually arranged with staggered vertical joints for extra strength, and are secured with $1\frac{3}{4}$ in. galvanised flat-head nails. Wire mesh is stretched over the cement boards, and the corners of the building, and also the corners of window and door openings, are given extra reinforcement with strips of wire mesh.

Framing for cement boards

Framing is constructed in the usual manner with studs at 18 in. centres and rows of dwangs at 27 in. centres;

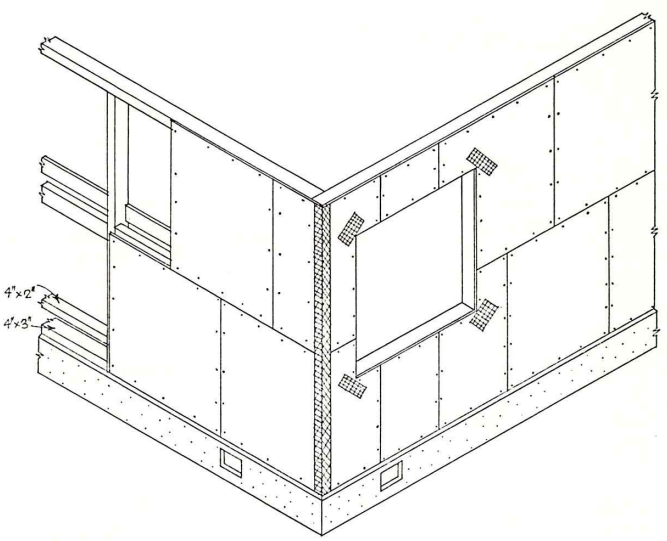


Fig. 296
Cement-board construction

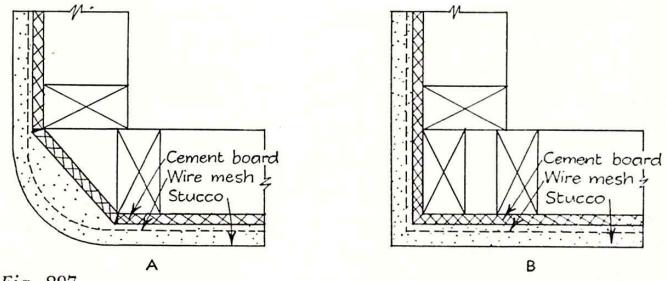


Fig. 297

Method of finishing corners

(A) *Rounded finish* (B) *Square finish*

the dwangs are sometimes placed with their wider sides towards the stucco to provide a good bearing surface (*Fig.* 298). In some cases a horizontal 4 in. x 1 in. stiffening piece is checked into the inside edges of the studs. Some types of rigid backing fit so closely to the framing that holes or V cuts (*Fig.* 299) must be made in the outside edges of dwangs and plates to allow for the circulation of air. Cement boards often have buttons cast on the backs of the sheets to prevent them from fitting tightly to the framing.

Rigid backing of mineral fibre cement sheets

Mineral fibre cement sheets are frequently used as a rigid backing material for stucco work. The framing must have holes or V cuts made in the edges for ventilation purposes.

Surfaces are covered with reinforcing mesh and the stucco is then applied.

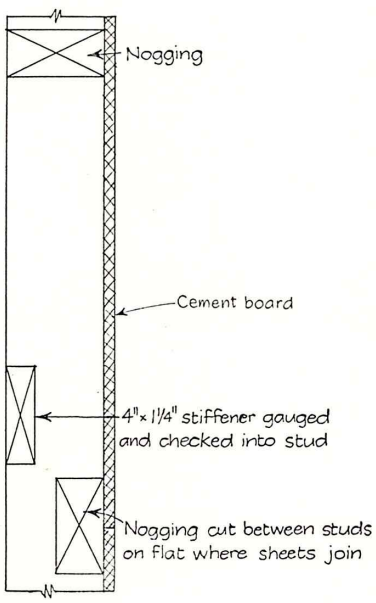


Fig. 298

Frame construction for cement boards

Rigid backing of timber sheathing

Buildings are given a rigid backing of timber sheathing of 6 in. x $\frac{1}{2}$ in. or 8 in. x $\frac{1}{2}$ in. boards closely boarded either diagonally or horizontally. Old houses are often given a stucco finish over the existing weatherboards which serve as a rigid backing.

Non-rigid backing for stucco

Non-rigid backing for stucco is provided by a heavy kind of building paper (10 lb. per 100 sq. ft.) or other suitable material that is well lapped at joints and secured with galvanised clouts. Galvanised wire mesh is stretched over the paper, and secured with furring nails which keep the mesh $\frac{1}{4}$ in. to $\frac{3}{8}$ in. from the surface of the paper. Although the building paper bulges between the studs when the stucco is applied, this does not have any deleterious effect on the work.

Application of stucco (*Fig.* 300)

Although the application of stucco concerns the plasterer, it is of value for the student to have some knowledge of what stucco is and how it is applied.

Stucco is a cement mortar made of three parts of sand to one part of Portland cement, to which a suitable waterproofing is added. Nowadays Portland cement mixed with clean sharp sand has been universally adopted for external stucco work.

Portland cement mortar for a stucco finish is usually applied in two or three coats, making a total thickness of 1 in. to $1\frac{1}{2}$ in. for non-rigid and $\frac{5}{8}$ in. to 1 in. for rigid backing. Any metal reinforcing must have at least $\frac{7}{8}$ in.

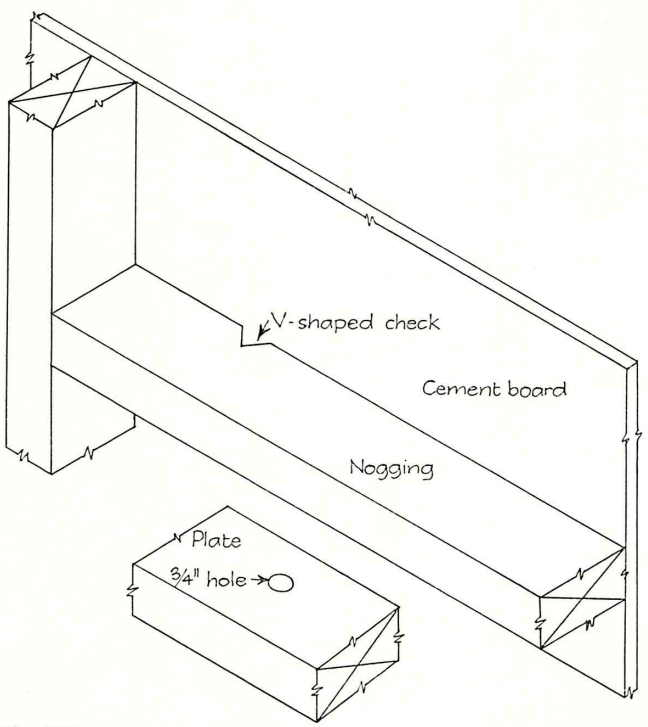


Fig. 299

Methods of ventilating stud walls

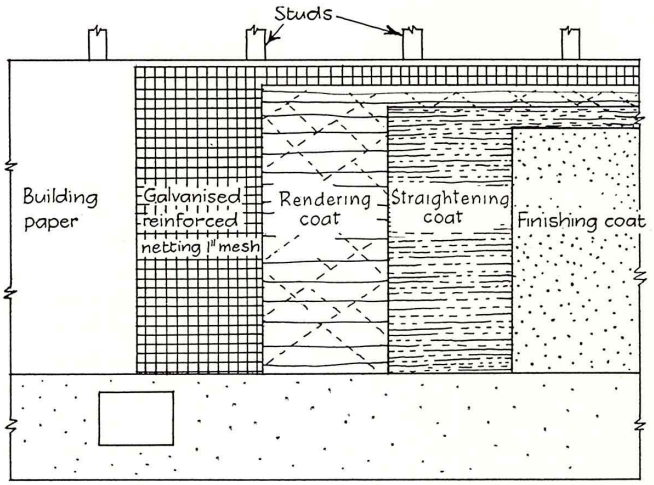


Fig. 300

Stucco work on timber frame

of cover. In good-class work three coats are employed, i.e., the rendering (scratch) coat, straightening (floating) coat, and the finishing coat.

When the backing material is of cement boards they should be wetted before work commences in order to prevent the stucco from drying too rapidly. The rendering coat should cover the reinforcing wire and be pressed firmly against the backing and trowelled to give a dense coat. Before the mortar has set, the surface of the work should be heavily cross-scratched to provide a strong key for the next coat. The first coat is allowed to dry for several days before the next coat is applied.

Before the straightening coat is applied the wall surface must be wetted to control suction. The purpose of the straightening coat is to form a true plane surface. This is accomplished by first arranging screeds of narrow bands of plaster or thin battens at convenient intervals on the wall surface and at corners and openings. When the cement mortar is applied a plasterer's straight edge or rule is used against the screeds to form a true surface. Before the mortar is hard the surface is scratched with a hard broom to form a key for the finishing coat.

The types of finish for external work include a smooth finish, textured (to represent stone surfaces), rough cast, pebble dash, and many other designs effected by various means.

Questions on Chapter 8

(1) Describe the various kinds of building paper that may be used in house construction and state how such a paper is fixed.

(2) (a) State the highest and lowest quality of weatherboards that may be used in sheathing the walls of a house.
(b) Why would you insist that non-heart weatherboards be treated with a preservative?
(c) Briefly describe a practical method of finding the number of weatherboards from the bottom to the top of a wall of a house.

(3) A house is to be sheathed with 6 in. bevel-back weatherboards that are to be mitred on the external corners of the building. Briefly state:
(a) How you would cut the weatherboards to length.
(b) The fitting of the lowest weatherboard on the wall.
(c) The method of fitting the mitres.

(4) Explain briefly the purpose of the following:
(a) Why is a brick veneer wall kept $1\frac{1}{2}$ in. from the timber framing?
(b) Why is a metal tray fixed below the sill of a window frame?
(c) Why is a bituminous compound used as a seal between a sash frame and the brickwork in brick veneer construction?

(5) Sketch and dimension a vertical section through a brick veneer foundation wall and footing. Show floor joists at right angles to the wall and also the lower portion of studs.

(6) (a) Show with a sketch the precautions taken to vermin-proof the walls of a brick-veneer house.
(b) What is the maximum height of a brick-veneer wall?

(7) Why are weatherboards not mitred on an internal corner?

(8) The weatherboards of a twenty-five-year-old house have decayed to such an extent that it has been decided to renew the wall surface with flat mineral fibre cement boards.
(a) Briefly describe the methods you would use to cover the walls with mineral fibre cement boards.
(b) Give an opinion as to why the weatherboards should have perished.

(9) A house has been designed for a stucco finish. Describe:
(a) How you would prepare the walls for the plasterer.
(b) In what way the joinery for a stucco finished house would differ from that necessary for houses with other sheathings.

(10) Describe how you would joint weatherboards in an internal corner of a house.

(11) A house is to be sheathed with mineral fibre cement sidings. Describe and illustrate how you would prepare the framing for the sidings and also how you would arrange the first and second row of sidings.

(12) Write a short specification covering the essential points for stucco work on timber framing.

(13) The walls of a house are to be sheathed with cement sheathing boards $\frac{3}{4}$ in. thick, the surfaces of which will later be plastered. Write a short description of how you would fix the boards and generally prepare for the plasterer.

(14) A brick-veneer wall is tied to the wall framing by twisted wire ties. Sketch such a tie and also show how the tie is secured in place.

(15) Why is it so important that mortar droppings should not accumulate in the cavity of a brick-veneer wall?

(16) What is the difference between rigid and non-rigid backing for a stucco finish.

Calculations

(1) Using decimals, find the number of full-width weatherboards required to cover a wall 8 ft. $3\frac{7}{8}$ in. in height if the cover of each board is $4\frac{1}{4}$ in.

(2) A builder has 10,000 linear ft. of $5\frac{1}{2}$ in. weatherboards. If each board covers $4\frac{1}{4}$ in., how many square feet of wall will the boards cover if 10 per cent is wasted in cutting?

(3) An area of 1,360 sq. ft. is to be covered with $5\frac{1}{2}$ in. bevel-back weatherboards. If the cover is $4\frac{1}{4}$ in. and 12 per cent is wasted in cutting, etc., calculate the number of ft. B.M. of weatherboards to be ordered.

(4) A batch of stucco is made from 1,917 lb. of sand, 953 lb. of cement, and 400 lb. of water. Find the percentage of sand, and of cement in the mixture. (Correct to one decimal place.)

(5) A brick-veneer wall is 8 ft. 9 in. high and is built of bricks $3\frac{1}{8}$ in. in depth, with mortar joints $\frac{3}{8}$ in. thick. How many courses of bricks are built up?

Chapter 9

FLOORING

The most common type of flooring board is that with a parallel tongue and groove, shown in cross section in *Fig.* 301A. The type shown in *Fig.* 301B is infrequently used but it is occasionally run for special jobs where secret nailing is necessary.

Note the following points shown in *Fig.* 301A.

(1) The thickness and various widths of board available.

(2) The dimensions of grooves are $\frac{1}{64}$ in. larger than the tongues for easy fitting.

(3) The boards are wider on the face side so that longitudinal joints between boards may be made tight on the floor surface.

(4) The grooves on the underside of boards are to reduce warping (*Fig.* 302).

Quality and grade

Flooring should be either of heart quality or treated timber.

Note: Ideal grades to specify would be, for example: Dressing A. Heart Rimu (D.A.H.) Rimu) or D.A.H. Matai. See N.Z.S.S. 1900, Chapter 6.1 Table 14.

Moisture content

If flooring is not seasoned when laid the joints will open and show wide cracks when the floor boards have completely dried. Floor boards with a moisture content from 12 to 16 per cent will not shrink unduly when used under normal circumstances, i.e., in buildings that are not centrally heated.

When partly seasoned flooring is delivered to the job, as sometimes happens, it must be further seasoned before being laid. Air-drying methods include:

(1) The filleting and stacking of the flooring in the open air or under cover.

(2) Cutting down the flooring on the joists, with the underside uppermost, where it can season for several weeks. It may then be turned over, cramped in position, and nailed.

Nails

Each floor board is usually double nailed to every joist with $2\frac{1}{4}$ in. or $2\frac{1}{2}$ in. floor brads placed about $\frac{1}{2}$ in. from the edges of a board (*Fig.* 303).

The nailing positions on the floor are usually sighted from the joists, but if it is necessary to keep to a dead straight line, a straight edge may be used as a guide to draw a line on the flooring above each joist.

Punching nails

Nail heads must always be punched below the surface of the floor with a nail punch. When a floor is to be sanded, the nails are usually punched just prior to the sanding operations; otherwise plaster of Paris from wall lining may fill the holes and this material has a detrimental effect on the abrasive paper on the sanding machine. Unpunched nail heads may tear the paper of sanding machines and, on floors not sanded, eventually wear holes in floor coverings.

Heading joints

The joints between the ends of floor boards are called heading joints and may be square or splayed.

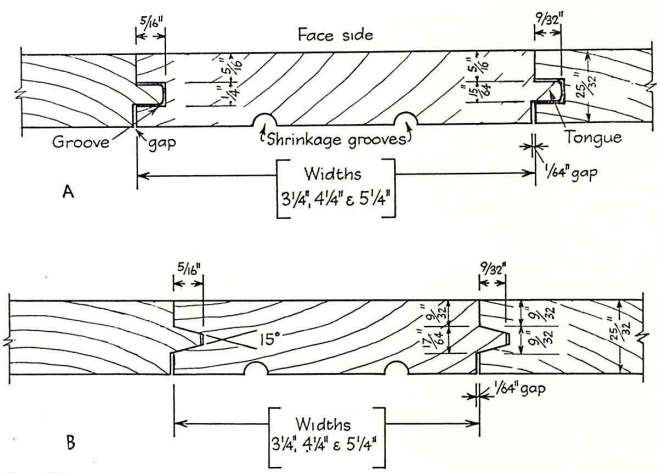
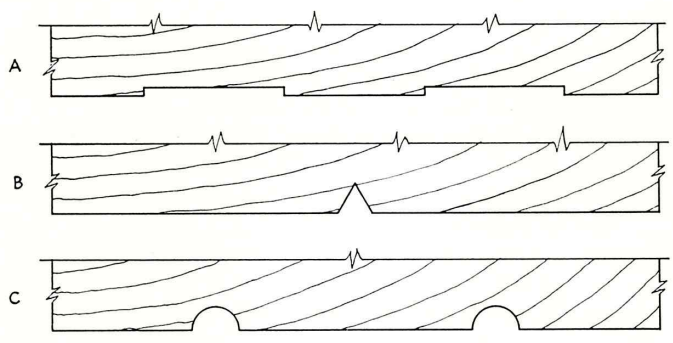


Fig. 301

Types of flooring

(A) *Common type of flooring board with parallel tongue and groove*

(B) *Type of board used for secret nailing*



Underside of flooring boards showing grooves to prevent warping

Fig. 302

Grooves to prevent warping

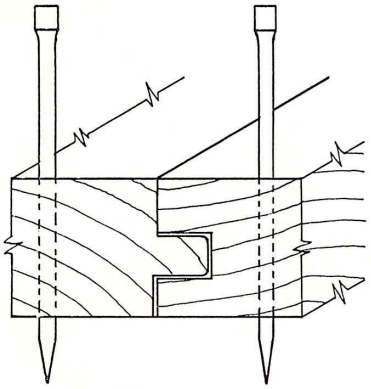


Fig. 303
Methods of nailing floor boards

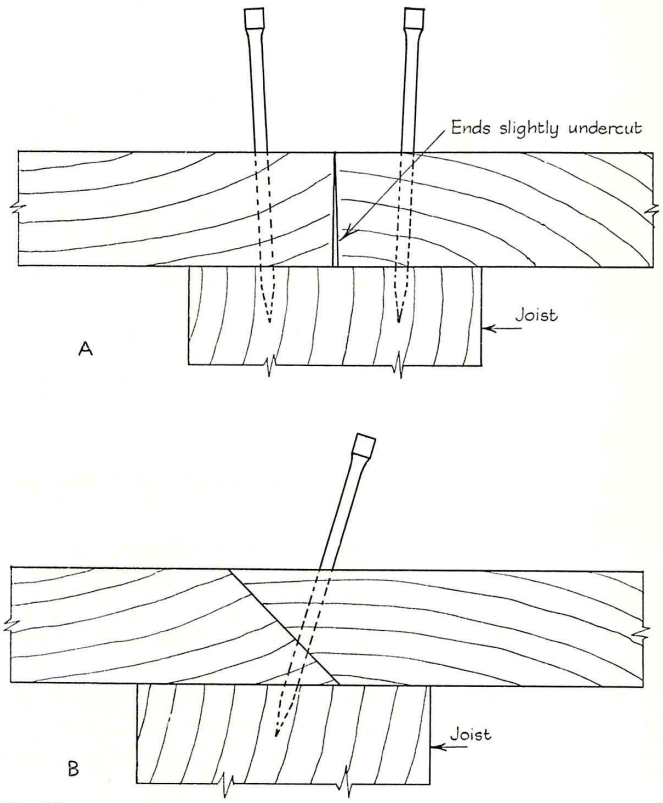


Fig. 304
Heading joints
(A) *Square heading joint*
(B) *Splayed heading joint*

Square heading joints (*Fig.* 304A)

Square heading joints are cut square across the faces of boards and undercut slightly so that the top edges may fit tightly. The ends of each board are double nailed.

Splayed heading joints

When the ends of boards are splayed only one board need be double nailed, as shown in *Fig.* 304B. The splayed heading will effectively secure the end of the adjoining board.

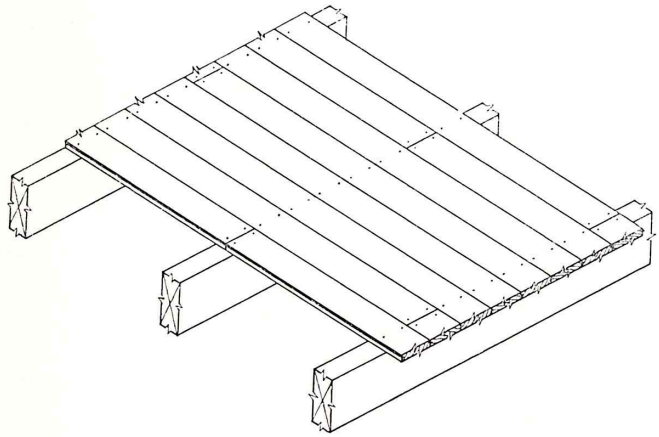


Fig. 305
View of floor boards showing staggered heading joints

Arrangement of joints (*Fig.* 305)

Heading joints should be staggered as widely as possible.

Handling of flooring

Care should be taken to prevent tongues or grooves of boards from being broken or damaged in any way.

To avoid turning long boards, end for end, inside the building, flooring should be taken in with the tongues and grooves the correct way for laying the floor.

Laying flooring

The layout of rooms and passages often determines where the first floor boards should be laid. A start may be made down the middle line of a building, for instance, in a hall or passage, and the laying of floor boards continued on either side until the outside walls are reached. On the other hand, the first boards may be laid on one side of the building and a finish made at the other side.

In both cases, the floor boards must be fitted about bearing partitions, while non-bearing partitions, which have been erected, are temporarily raised, and the floor laid under them.

Cramping of flooring

Floor boards are cramped tightly together with floor cramps (*Fig.* 306) or, if only a few boards are being laid, a heavy chisel may be used to lever the boards into place. The first board, a straight one, is laid on the joists against the wall chosen as the best starting place and nailed on the edge nearest the wall. Five or six boards are then laid, as tightly as possible, in preparation for cramping together. As shown in *Fig.* 307, a heavy hammer is often used to force the boards together before the cramps are applied. A straight piece of scantling is laid on the joists beside the outside board and floor cramps are used at every third or fourth joist to squeeze the boards together. Care must be taken not to displace the first board laid and the partition or wall alongside it.

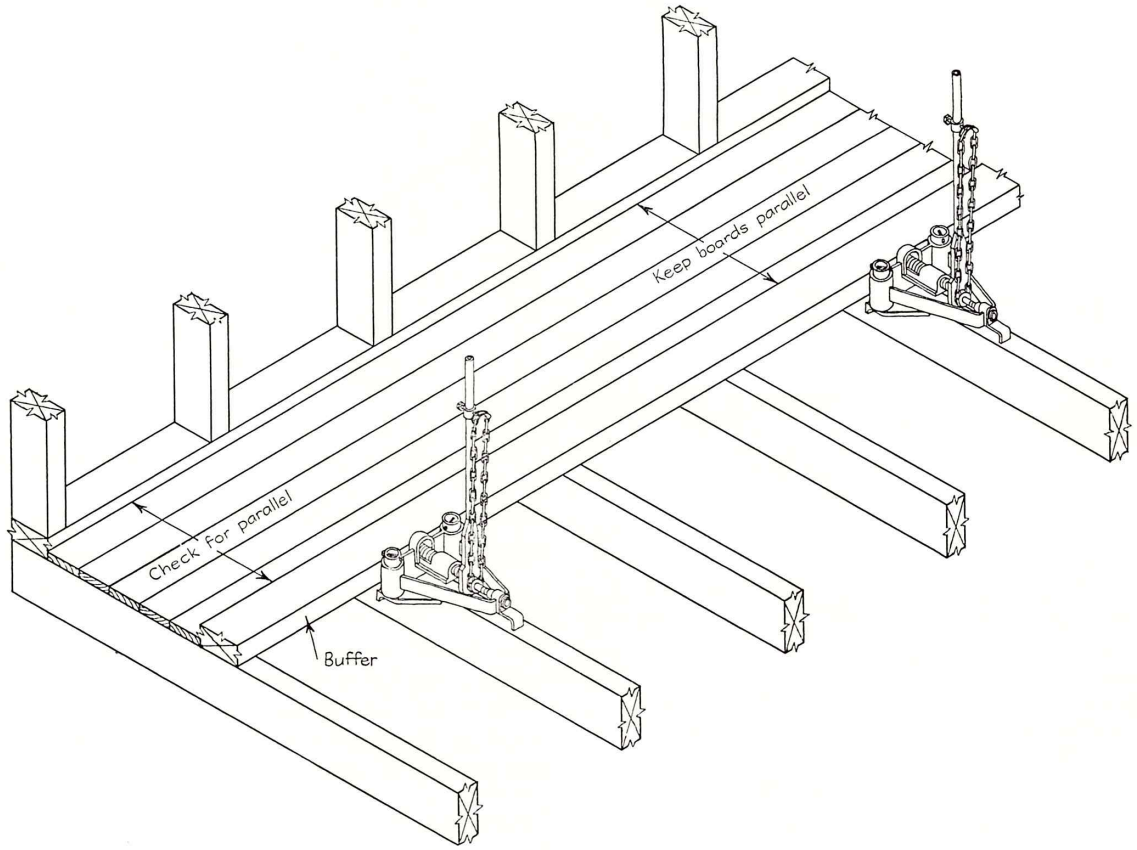


Fig. 306

Cramping of floor boards

After the first lot of boards has been nailed subsequent ones may be cramped until the boards are raised to a slight camber.

The nails are omitted, or partly driven, at the leading edge of the front board nearest the cramps, to give more freedom for the entering of the next board. Double nailing of the rest of the floor boards is commenced nearest the cramps and continued in a direction away from them.

The cramping of boards has a tendency to open heading joints. If this occurs the cramps are slackened slightly, the boards tapped or levered endwise until the joints are closed, and then the cramps are tightened again.

After every second lot of boards has been cramped, the leading edge is sighted for straightness and a check is made with a measuring rod to see that the edge is parallel with the starting line. If the work becomes "out of parallel" it can be corrrected by adjusting the pressure with the floor cramps on subsequent boards.

On the last 18 in. of flooring there is insufficient space to operate the floor cramps; so the joints must be made tight by one of the following methods:

(1) Levering the edge of each board with a chisel.

(2) Levering with a piece of scantling or pinch bar from the adjacent wall (*Fig.* 308).

(3) "Springing" or "folding" in the last few boards.

Fitting last board (*Fig.* 309)

On most occasions the last board may be fitted to the bottom plate as follows:

Several boards are tightly laid to a distance of less than a board width from the wall plate and held in position by temporary nailing. A piece of floor board with

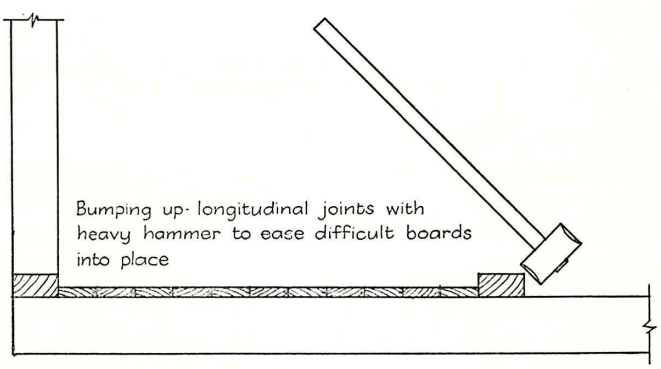


Fig. 307

Bumping of boards into approximate positions

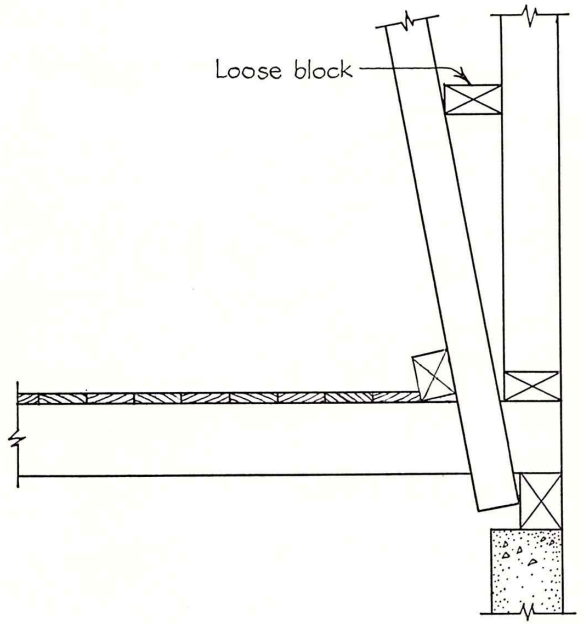


Fig. 308

Use of lever for cramping boards near a wall

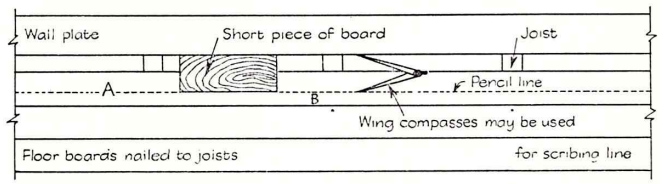


Fig. 309

Marking width of last board

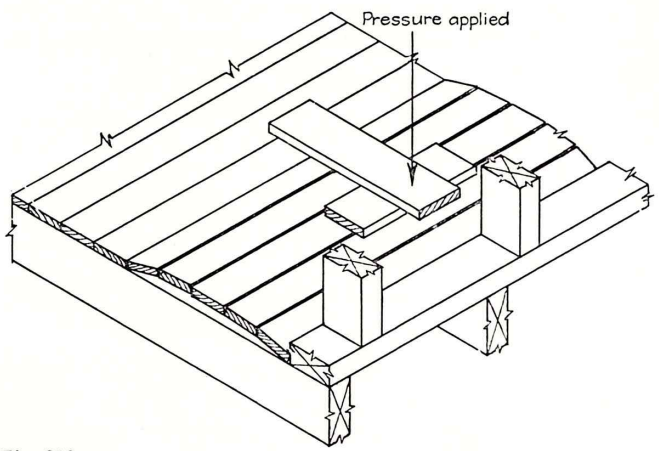


Fig. 310

Method of "folding in" last boards

the tongue removed is held against the bottom plate as a width gauge, and a line is marked along board A (*Fig.* 309) which is ripped to width and piece B is placed against the bottom plate. The boards are now arranged as shown in *Fig.* 310, folded into position, and nailed in the usual manner.

Finish about hearth

The trim about an opening in a floor for a hearth, etc., is ususally effected by the use of margins aranged in any of the several ways shown in *Fig.* 311.

In cases where the hearth slab is on the floor and covers the joint about the opening, the flooring is usually cut flush with the sides of the opening or trimmer.

Finish about chimneys

The flooring should be fitted tightly against the sides and back of the chimney base to exclude vermin.

Sanding of floors

Although floor boards may have been accurately machined and laid, the joints between boards are at times uneven and must be dressed flush with the floor surface. The modern method of smoothing floors is to sand the surface with power-driven machines using abrasive paper attached to rollers. When floors are sanded in two operations the first paper used is No. 1½ (coarse) and the finishing paper No. 0 (fine). The machine is worked with the grain of the wood and a finish made close to the skirting. The floors of wardrobes and coat cupboards are sanded at the same time as the rest of the floor.

Secret nailing

The type of floor board shown in *Fig.* 312 has a strong tongue which makes it suitable for secret nailing.

The method of cramping and nailing each board is shown in *Fig.* 313. One line of boards at a time is levered into place with a heavy chisel and skew nailed near the tongue.

Access doors (*Fig.* 314)

Access under a building, when not provided by a door in the foundations, is usually made through an opening (trap door) in some suitable position such as in the laundry floor.

An opening about 24 in. x 16 in. is trimmed between the floor joists and the flooring finished against a margin in the usual manner. The flooring boards over the opening are fixed to battens and a flush ring, for lifting the trap door, is recessed at one end of the door. It is not usually hinged.

Note: In two-storey buildings trap doors are placed in the upper floor for access to the electrical installation.

Flooring in exposed positions

Flooring on an open verandah should have an arris run on the top edges of boards to form a vee when cramped

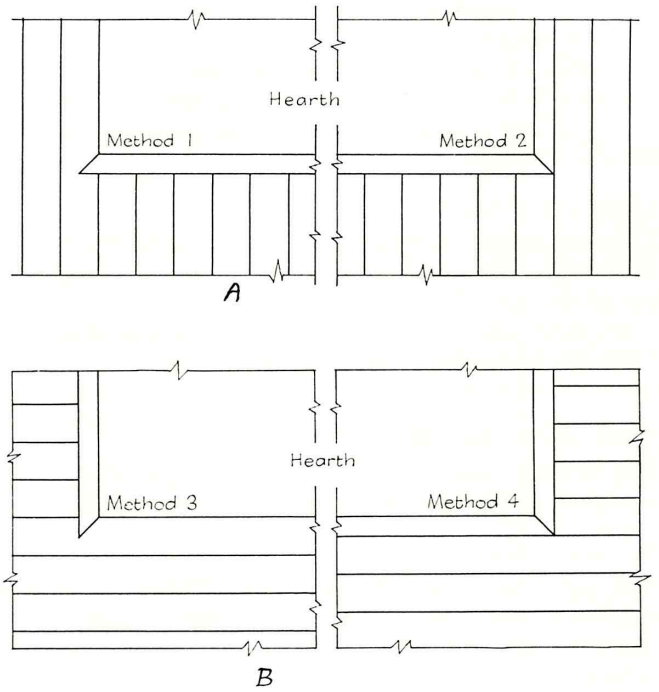


Fig. 311

Arrangement of floor boards about hearth

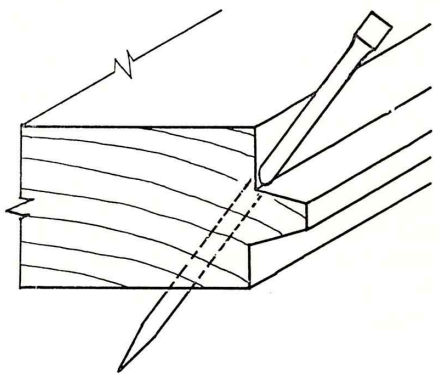


Fig. 312

Skew nailing

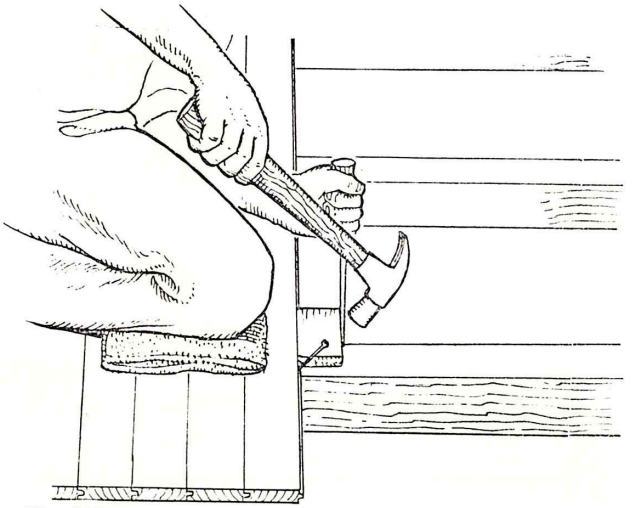


Fig. 313

Method of cramping and skew nailing

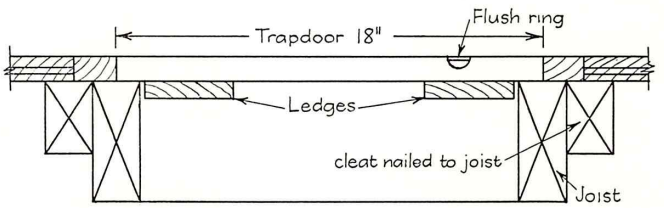


Fig. 314

Trap-door arrangement

together. Edges should be primed with paint before the boards are laid, and the floor surface later given several coats of paint for protection against the weather.

Exterior wooden floors are often laid with square-edged boards spaced $\frac{1}{2}$ in. to $\frac{3}{4}$ in. apart.

Calculation of quantities of flooring

When finding the quantity of flooring required to cover certain areas, an allowance for the reduction in width due to milling and a percentage allowance for waste in cutting must be made.

$$\text{Total number of ft. B.M.} = \text{area} \times \frac{\text{original width}}{\text{finished width}} \times \frac{(100 + \text{R})}{100}$$

R = percentage allowance for waste.

Example 1. Calculate the quantity of the T. and G. flooring required for a floor measuring 36 ft. by 32 ft. The boards are to be milled from $4\frac{1}{2}$ in. timber finishing 4 in. Allow 6 per cent for waste in cutting.

$$\text{No. of ft. B.M.} = (36 \times 32) \times \frac{4\frac{1}{2}}{4} \times \frac{(100 + \text{R})}{100}$$

$$= \frac{36}{1} \times \frac{32}{1} \times \frac{9}{8} \times \frac{106}{100}$$

$$= 1374 \text{ ft. B.M.}$$

The above formula is also used for calculating the quantities of T. & G. linings and all types of lapped weatherboards. When using the formula for calculating weatherboarding the term, "finished width" is replaced by "cover".

Questions on Chapter 9

(1) Write a short specification describing the quality and kind of flooring to be used in a house where the top edges of the floor joists are:
(a) 3 ft. 6 in. above the ground.
(b) 7 ft. 4 in. above ground level.

(2) Describe the process of:
(a) Laying and cramping floor boards.
(b) How would you lay the last few boards if the last one against the wall is not a full-width board?

(3) Sketch and dimension a full-size profile of a flooring board with a parallel tongue and groove. Show one device that is used to prevent a board warping.

(4) How many feet B.M. of flooring of a nominal width of 6 in., which is reduced to $5\frac{1}{4}$ in. after dressing, would be required for a floor 24 ft. wide and 45 ft. long? Allow for a 10 per cent waste.

(5) (a) If flooring with a high moisture content is delivered to a job how would you dry it so that it may be laid?
(b) If the floor surface in a house is to have a varnished finish what precautions would you normally take to ensure a good job?

(6) Sketch full-sized cross sections of two kinds of joint that may be made between the ends of floor boards.

Calculations

(1) What fraction of the width of a floor board is wasted when boards are machined out of 6 in. x 1 in. timber and finished $5\frac{1}{4}$ in. wide?

(2) A floor is 40 ft. long and 18 ft. 7 in. wide. How many 18 ft. lengths of $3\frac{1}{4}$ in. wide flooring are required?

(3) A floor is to be covered with flooring of $3\frac{1}{4}$ in. finished width. What is the percentage waste in machining the timber from 4 in. x 1 in. timber?

(4) A floor 24 ft. 9 in. x 49 ft. 6 in. is to be covered with 6 in. x 1 in. tongued and grooved flooring boards. How many feet B.M. are required if 12 per cent is to be added for loss of width of the boards when they are machined and on cutting down, an additional 10 per cent waste is incurred?

(5) Calculate the cost of flooring required for a floor 33 ft. wide and 52 ft. long if flooring costs 99s. per 100 ft. B.M. and the boards are to be milled from 4 in. boards which have a finished width of $3\frac{1}{4}$ in. Make allowance for a 10 per cent waste in cutting into place.

Chapter 10

FIXING JOINERY

Joinery for a house

The joinery for an average house includes window frames and sashes, door frames and doors, kitchen fittings, sill boards, skirtings, architraves, cornices and mouldings generally. In a two-storey house the stairs and handrails would be included in this list.

Most timber for joinery is kiln dried to a moisture content ranging from 14 to 17 per cent for interior joinery and 19 to 23 per cent for exterior joinery. Sills are usually air seasoned to a moisture content of about 23 per cent.

Windows

Windows provide light and ventilation and are arranged in sizes according to the dimensions of rooms and the purposes for which such rooms are intended to be used.

Sizes of windows

New Zealand Standard Specifications require that the net glazing area (that is, the actual surface area of the glass) in windows of rooms used for living purposes must be at least one-tenth of the floor area of such rooms, and also that one-half of such glass area must be constructed so that it will open for purposes of ventilation.

Basic types of window frames

There are many types of windows in common use, named according to the type of frame or the treatment of the sash. In general, window frames are of three kinds:

(a) The "solid frame" is made of sufficiently large timbers to support the weight of the sashes. This type of frame is used for casement, horizontal sliding, pivot-hung, fixed sashes, and louvred windows.

(b) The double-hung window frame for vertically sliding sashes is constructed of comparatively thin members. When balancing weights are used a box is formed on either side of the frame for the weights, but nowadays, with spring balances mostly in use, these boxes are unnecessary as the spring balances are fixed on the inner side of the jambs of the frame.

(c) Metal windows of the casement and pivoted types are manufactured in a wide variety of designs. Such windows should be made from rust-resistant material, or effectively treated against rust. Under such circumstances they give long service when properly installed and maintained. Steel window frames, untreated against the action of rust, soon corrode to such an extent that members become buckled and eventually the frames have to be removed.

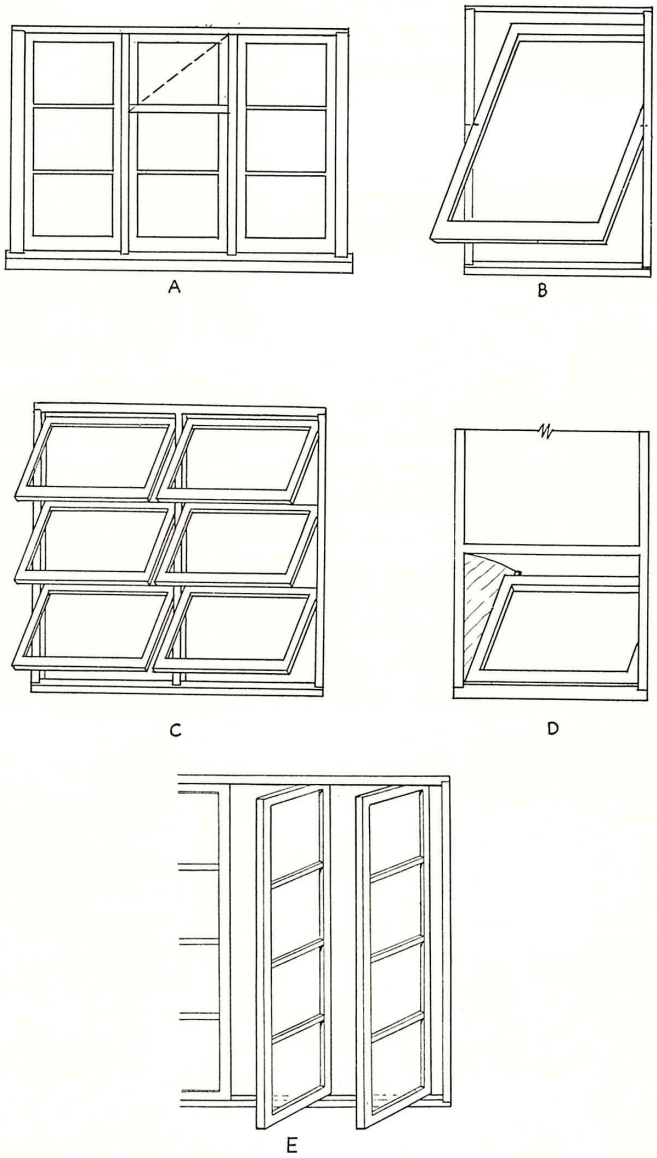


Fig. 315

Types of sashes

(A) *Casement frame and sashes*
(B) *Horizontally pivotted sash*
(C) *Awning-type sashes*
(D) *Hopper-type of window*
(E) *Vertically pivotted sashes*

Types of sashes

Casement sash (*Fig.* 315A)

A casement sash is attached to the window frame by hinges on the vertical edge of the sash so that it may be opened outwards. A sash that is hinged at the top horizontal edge is known as a top-hung casement.

Sashes are frequently pivoted on their sides or ends allowing them to be turned or opened in one direction or another. The sash shown in *Fig.* 315B is pivoted just

above the middle point of its stile and the sashes in *Fig.* 315C have fittings that allow the sashes to be opened as an awning. The hopper window in *Fig.* 315D has the sash opening inwards. The fittings on the sashes in *Fig.* 315E vertically pivot to open the sashes to a position where the outside glass surface may be easily cleaned from within the room.

Fixed sashes

As the name implies, fixed sashes are those which are permanently secured in a frame and cannot be opened.

Fanlights

A fanlight is a small sash over a window or door used for lighting and ventilation. It may be pivoted or hung on hinges from either the top or bottom edge.

Louvres (*Fig.* 316)

A louvre is a ventilator consisting of a framework holding inclined blades of wood, glass, or metal, spaced to allow the free passage of air and, when necessary, light, but to exclude rain. The louvre blades may be fixed or adjustable.

Louvres with fixed blades are used to provide ventilation for roofs, toilets, food safes, etc. They are used also as shutters in window openings to afford shade from the sun, being hinged vertically to fold back against the outside wall.

The angle or pitch of louvre blades may vary between 45° and 60° to the horizontal, depending on the position the louvre frame is to occupy in the building.

The jambs of the louvre frame are grooved to receive the louvre blades. If glass blades are used, they are slipped into the grooves loosely. If timber blades are used, they are nailed permanently.

Adjustable glass louvres

Louvre windows with adjustable glass blades held in metal fittings are now used extensively in New Zealand buildings.

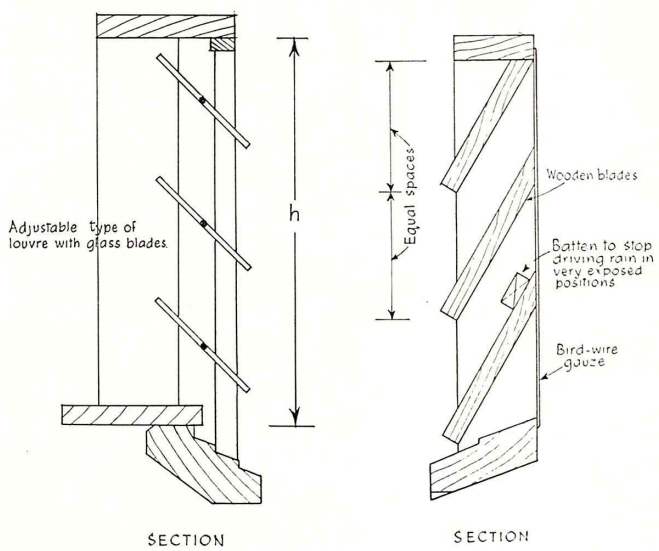


Fig. 316

Two types of louvre

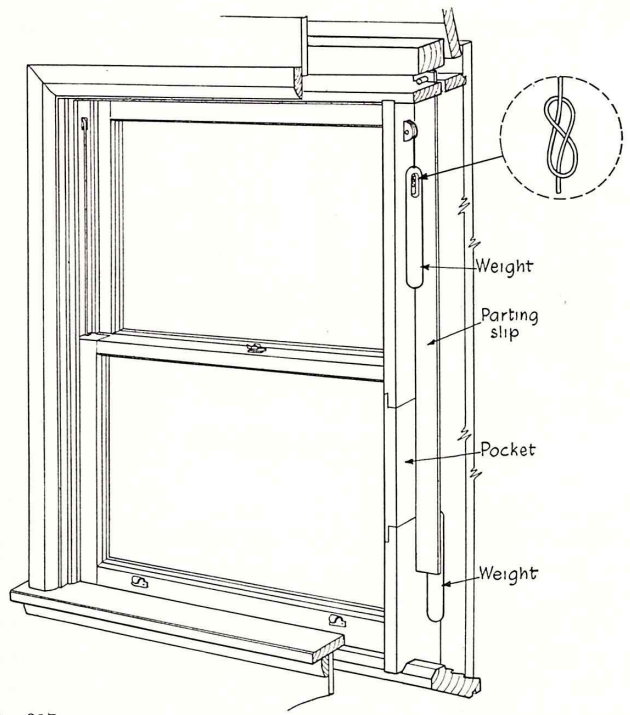


Fig. 317

Vertically sliding sashes

The glass blades in the window can be opened to any required angle by means of a handle situated in the side of the fitting. The angle at which the glass blades are placed efficiently controls the volume and direction of the air entering a room. When partly closed, the louvres direct the air upwards thereby preventing draughts.

There are several types of louvres in use but they all work on a similar principle. Some are horizontally pivoted near the top edge or at some distance from the centre.

Sliding sashes

Sashes may be made to slide horizontally or vertically.

Vertically sliding sashes (*Fig.* 317)

Vertically sliding sashes are arranged as a pair of equal-sized sashes both of which may be moved vertically in grooves in the frame. These sashes may be balanced by springs, now used the more commonly, or by weights.

Horizontally sliding sashes (*Fig.* 318)

These sashes may be moved horizontally on brass rollers with tracks secured to the head and the sill of a frame or to the sill only. Some types of fittings allow the sashes to be folded together and moved horizontally at the same time.

Direct glazing of window frames is a modern practice of fitting window glass into shallow rebates in the window frame, thus dispensing with the necessity for the usual sash. Windows that open cannot, of course, be arranged in this manner.

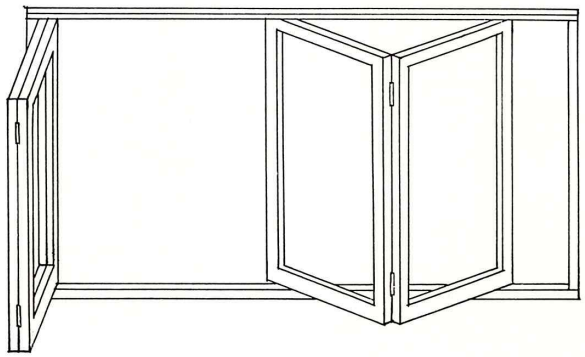


Fig. 318

Horizontally sliding sashes

Fitting window frames

Window frames are usually delivered to the job squared and braced, and the work of a carpenter is to fit the frames into the openings in the walls.

The height and width of a frame is usually marked on a light rod and these dimensions checked with those of the opening. One-half an inch clearance is allowed around the frame, except at the sill which rests on the trimmer.

It is impossible to deal with the fitting of all the many kinds of window frames in the various types of wall construction, but two common methods of fitting a casement frame into a weatherboarded wall will be described.

(1) Fitting the frame outside the actual opening.

(2) Taking such measurements as are required to trim the frame at the bench and then hoisting it into position.

Method 1

The frame is supported outside the opening and the horns at each end of the head are marked for a sliding fit between the trimmer studs. The sill is scribed to fit against the weatherboards. To avoid error it is advisable to place the frame as close as is possible and parallel to the weatherboards, and the sill must be in its exact position as to height. To have the frame close to the wall the horns at the head of the frame are sawn off to length, and the back portion of each sill horn is split off about 1 in. behind the facings, allowing only enough timber for scribing purposes. When the frame has been placed parallel with the wall, the ends of the sill are scribed to the slope of the weatherboard behind the sill. This is done with wing compasses open to that distance from the lower front edge of a weatherboard to the back of the facing.

Fig. 319 shows a vertical section of the final position of the sill in relation to the weatherboards.

Instead of placing the frame in position, it is sometimes an advantage to cut a $\frac{1}{2}$ in. piece from an odd length of sill, should such be available, or to make a template to the shape of the sill. Place this in position and mark it as described, these marks being then transferred to the actual sill.

When the back of the sill has been sawn to shape the ends are cut square, to show a return on the sill equal to the distance that the front edge of the sill projects beyond the front of the facing. Do not forget to allow for the thickness of scribing beads on each side of the frame.

Method 2

This method is particularly useful for large heavy windows which have to be fixed from a scaffold in a high awkward place. It is usual to gather sufficient data so that the frame may be sawn to the correct sizes while on the ground and then hoisted into position. If the work has been accurately done there should be no difficulties. The detailed steps of the process are as follows (refer to *Figs.* 320, 321):

(1) Tack a short length of batten to the weatherboards flush with the opening. The back of this batten occupies the same position, relative to the weatherboards, as the back of the facing of the frame will occupy when it is finally nailed into position.

(2) Draw the line AD on the trimmer stud (*Fig.* 320) showing where the line of the bottom edge of the sill will run. This line just touches the top front edge of the trimmer.

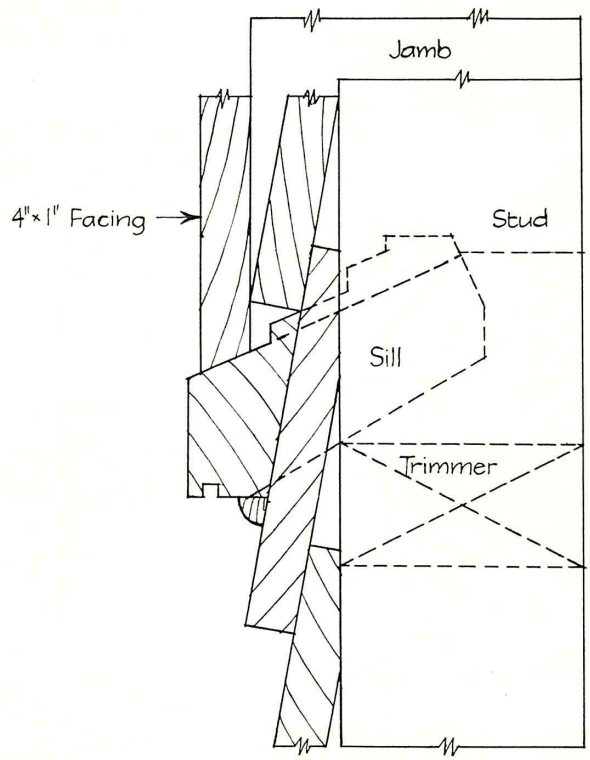


Fig. 319

Position of sill against weatherboard

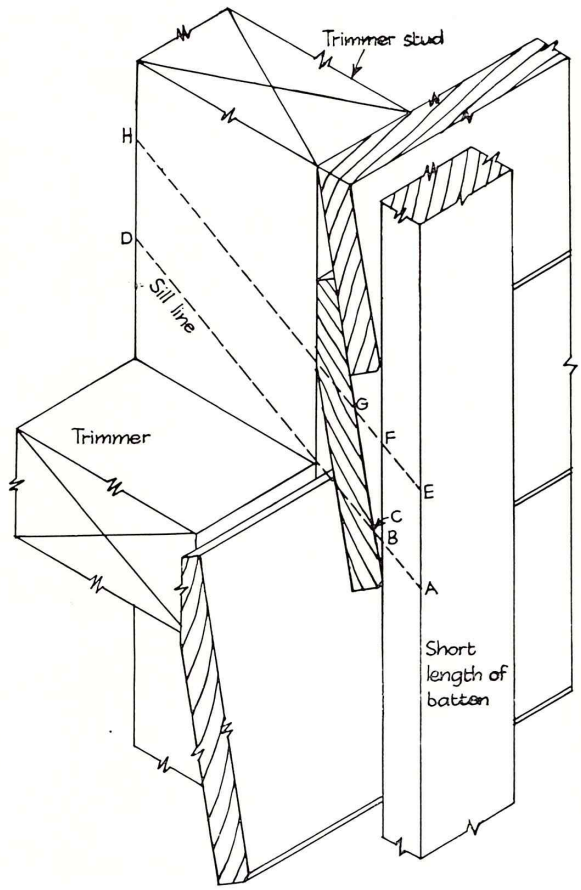


Fig. 320

Finding position of windowsill

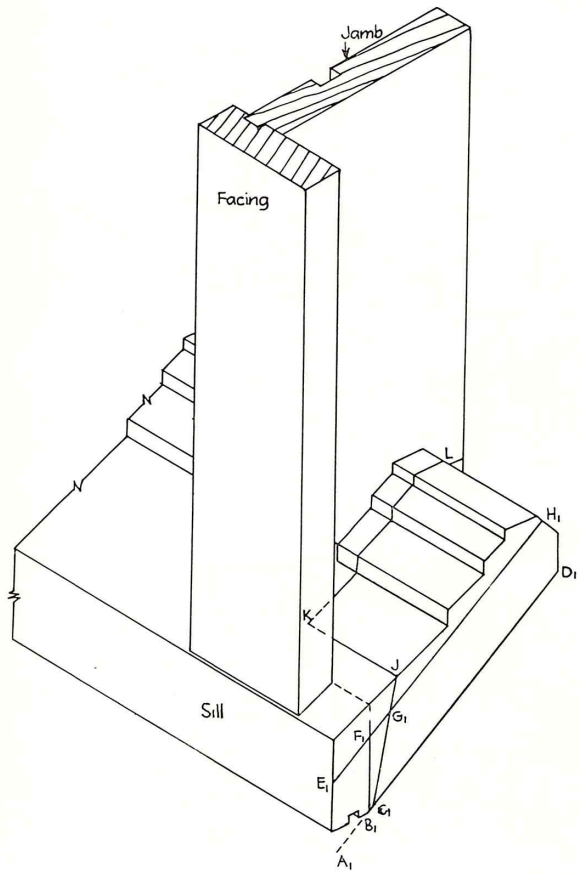


Fig. 321

Marking of windowsill

(3) Draw the line EH parallel to AD and at a distance away from it less than the depth of the sill. A 3 ft. rule folded and held on the flat will give the right distance.

(4) Lay the window frame on saw stools.

(5) Draw the line E_1H_1 (*Fig.* 321) on the end of the sill and parallel to the bottom of the sill. Make sure that this line is the same distance away from the sill line as EH is in *Fig.* 320.

(6) Project a line along the back of the facing to the edge of the sill and plumb down. This gives E_1 and B_1 corresponding to the points F and B in *Fig.* 320.

(7) Measure the distance on the slope between F and G and B and C (*Fig.* 320). Transfer these measurements to the sill (*Fig.* 321) and so arrive at points G_1 and C_1.

(8) Join C_1G_1 and produce to the top edge of the sill point J.

(9) The line LK is marked, say, $\frac{3}{8}$ in. away from and parallel to the jamb. The distance LK is away from the jamb is governed by the clearance between the jamb and the trimmer stud, as this part of the sill has to slide in alongside the trimmer stud.

(10) Cut the sill along C_1JKL (*Fig.* 321).

(11) Cut the end of the sill square across at a distance of $\frac{7}{8}$ in. from the edge of the facing. This allows $\frac{5}{8}$ in. for the scriber and $\frac{1}{4}$ in. for overhang.

(12) Scribe the sill in the same way at the other end.

Fixing window frames

After a window frame has been fitted, it is placed in position; the sill is levelled and the jambs plumbed before the frame is finally secured by nailing through the facings to the studs. The sill may be skew nailed at the ends, or holes may be bored and 4 in. nails driven through the front edge of the sill. Sometimes it is necessary to secure a long sill by driving nails through the sill to the trimmer below it.

It is usually the job of the plumber to insert galvanised iron or copper trays (*Fig.* 322) under the sill to deflect to the outside any water that may gain entry.

All windowsills must be supported by blocks placed between the underside of the sill and the trimmer. These blocks are located under, or close to mullions and jambs. A long windowsill requires extra blocks spaced at about 18 in. centres.

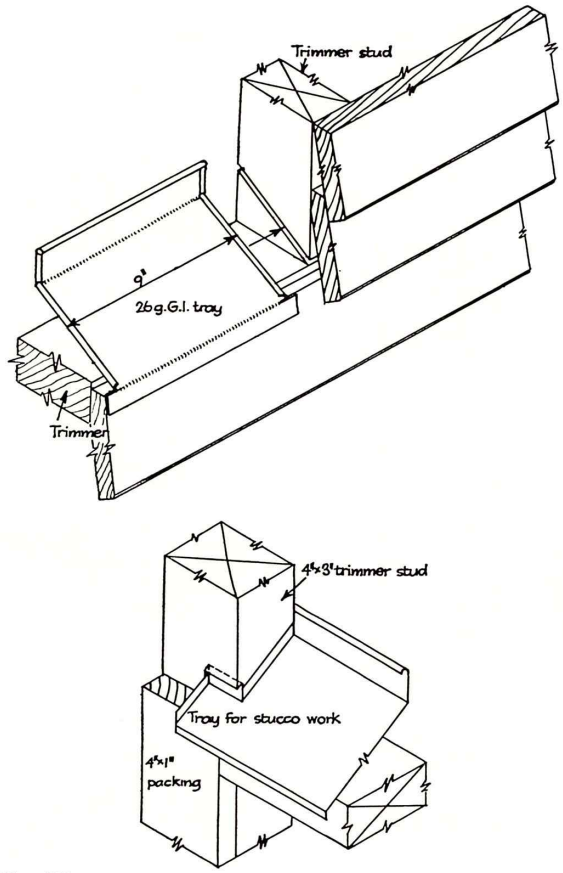


Fig. 322
Sill trays for weatherboard and stucco finish

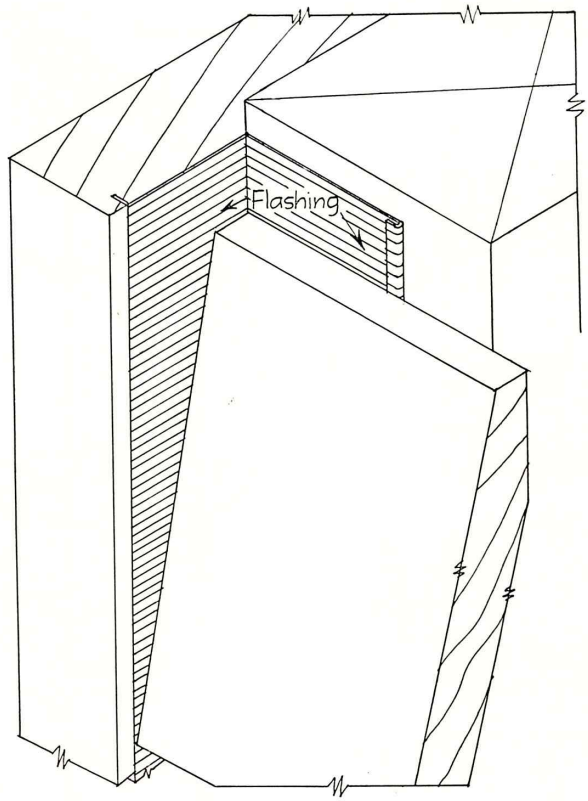


Fig. 323
Side flashing for window frames without facings

When fixing more than one frame in a wall it is advisable to have the lower edges of all the window sills in a horizontal line.

Although the sashes have been fitted and temporarily secured in the frame, or transported to the job independently of the frames, it sometimes happens that the sashes will not fit on account of the frames having become racked during transport and handling. It is then necessary to remove the bracing from the frames and to re-square them. This is usually done before a frame is securely nailed.

Window frames without facings

Many window frames do not have facings, so that the weatherboards are butted against the jambs which extend about $\frac{1}{4}$ in. past the front line of the weatherboards. To make a watertight joint between the ends of the weatherboards and jambs, a side flashing (*Fig.* 323) must first be turned into a saw cut in the jamb and under the ends of the weatherboards. Care must be taken not to pierce the flashing with nails.

Fitting window frames without facings

Casement frames without facings are fixed in position before the outside sheathing.

The horns of the head are cut to make an easy fit between the trimmer studs.

The sill is cut flush with the outsides of the jambs.

The frame is lifted into position and fixed in the same way as previously described.

The jambs will stand beyond the outside of the rough framing by slightly more than the maximum thickness of the outside sheathing. For a bevel-back weatherboard job this would be at least $1\frac{1}{2}$ in.

Before the sheathing is fixed flashings have to be placed in position (*Fig.* 323).

When fixing weatherboards against the jambs, care has to be taken that each weatherboard is a neat fit and does not push the jamb away from the weatherboard below.

Windows in stucco construction

There are various ways of finishing stucco at window frames but we will deal with two of the more common methods.

In one finish the window facings are kept flush with the rough framework and the stucco is carried across and then keyed into special grooves in the facings. This means that the trimmer studs have to be kept back the thickness of the facing and therefore 4 in. x 3 in. trimmer studs on their flat are used. *Fig.* 324A shows a vertical

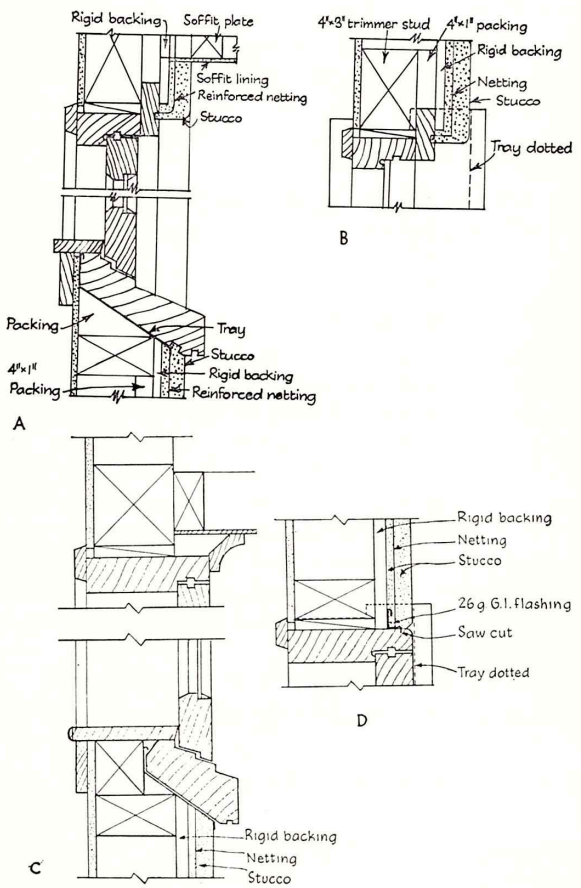


Fig. 324

Stucco finish about window frames

(A and B) *Vertical and horizontal sections through window frames with facings*

(C and D) *Vertical and horizontal sections through window frames without facings*

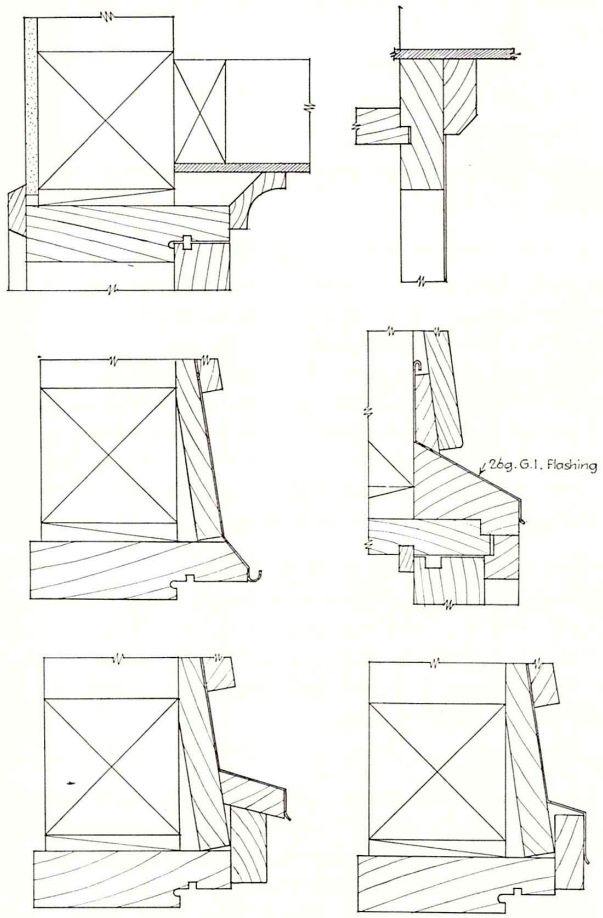


Fig. 325

Types of finish above window and door frames in weatherboarded walls

section through a window in this type of construction, and *Fig.* 324B a horizontal section through a jamb.

In another finish, shown in *Fig.* 324 C and D, no facings are used and the stucco finishes flush with the outside edges of the jambs. A metal flashing is inserted behind the joint.

Windows in brick-veneer

The methods of fixing windows in brick-veneer work are dealt with in the section of the work on brick-veneer. See Chapter 8, page 161.

Flashings

Unless a window frame is sheltered by a soffit or other overhang a sheet metal flashing must be placed across the head of the frame. The various methods employed are shown in *Fig.* 325.

Finish about window frames

The various kinds of finish that may be used about a window frame depend to a large extent on the type of window frame and the wall sheathing used. On a weatherboarded job the facings of the frame are made weathertight with scribers fitted against the vertical edges of the facings. Frequently the head of a frame is in close proximity to a soffit and under such circumstances a neat finish is made between the frame and soffit with a scotia or other such moulding. Under the sill of the window frame a scotia is used to cover the joint between sill and weatherboard. This piece of moulding is returned at the ends and is of a length equal to the total width of the frame across facings.

Doors

Doors are designed and constructed to suit either an external position, when they are made to withstand the effects of the weather, or an internal position, where they are of a serviceable and suitable design to match the surrounding finishings.

Doors are named in accordance with their size, construction, type, location, and method of hanging; e.g., sliding, hinged, folding, swinging, and revolving.

The following is a classification of the types of doors generally in use:

(1) Ledged and braced.
(2) Framed and ledged.
(3) Panelled.
(4) Flush doors (solid and hollow-core types).
(5) Glazed doors.

Ledged and braced doors (*Fig.* 326A)

The simplest type of door is the ledged door made of tongued and grooved sheathing boards secured to ledges, but such a door is unsatisfactory because it is not braced. The ledged and braced door is an improved type of ledged door with diagonal braces which stiffen the door and prevent the dropping of the edge furthest from the hinges. If the braces are placed the wrong way, i.e., in tension instead of compression, they merely pull away at the ends and become ineffective.

Framed and ledged doors (*Fig.* 326B)

This type of door consists of a frame made of stiles and rails to which tongued and grooved V-jointed sheathing boards are secured. Braces are usually omitted in the 2 ft. 6 in. to 2 ft. 8 in. framed ledged doors but are fitted in the larger sizes of door.

Panelled doors (*Fig.* 326C)

Panelled doors are made of stiles, rails, and sometimes muntins framed together with mortise and tenon joints. The edges about the panels may be left square or bevelled, moulded, or simply bevelled on the top ledges only. More elaborate panelled doors may have raised panels and planted mouldings.

Glazed doors (*Fig.* 326D)

Glazed doors like sashes are rebated, and may be divided into any number of panels with horizontal or horizontal and vertical glazing bars.

Part-glazed doors

These may be frame-ledged, panelled, or flush types of doors with the upper portion left open and rebated for glass.

Flush doors (*Fig.* 327A, B)

During the past few years the flush door has steadily increased in popularity until it is now recognised as the standard type of door for use in modern buildings.

Flush doors are constructed of a core of timber covered on both sides with plywood or with two layers of veneer. Clashing strips protect the edges of the plywood or veneer and improve the appearance of the edge by covering the end grain of the plywood or veneer and the core timber with wood of the same species as the face veneers. *Fig.* 328 shows how clashing strips are secured to the edge of a door.

The core of a flush door may be constructed as:

(1) A framing of stiles and rails (hollow-core) (*Fig.* 327A): or

(2) A built-up solid core (solid core) (*Fig.* 327B)

Common door sizes

Interior doors may have respective widths of 2 ft. 4 in., 2 ft. 6 in., or 2 ft. 8 in. and a common height of 6 ft. 6 in. Doors for wardrobes are usually 2 ft. wide and 6 ft. high.

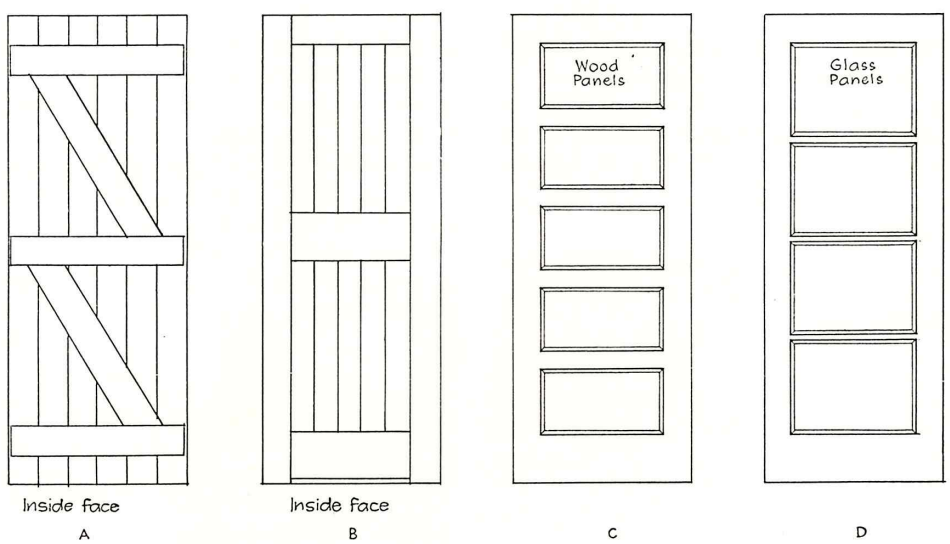


Fig. 326

Types of doors

(A) *Ledged and braced* (B) *Framed and ledged* (C) *Wood-panelled door* (D) *Glass-panelled door*

Exterior doors are made in widths of 2 ft. 8 in. and 2 ft. 10 in. with a height of 6 ft. 6in.

The thickness of flush doors is usually $1\frac{9}{16}$ in., while other types of doors are $1\frac{5}{8}$ in. thick. Wardrobe doors (6 ft. x 2 ft.) should be $1\frac{1}{8}$ in. thick.

Door frames (Fig. 329)

Doors are fitted and hinged to a frame which forms a lining about the "rough" opening in a wall. The vertical members of a door frame are known as jambs; the top horizontal member being the head, and the bottom member the sill. Door frames in exterior positions are usually made of solid rebated timber and frames in interior positions are of solid rebated or built-up jambs with planted stops.

Door frames in exterior positions should be specified as "exterior door frames with sills" or where concrete thresholds are required "exterior door frames without sills". An interior door frame is often referred to simply as a set of jambs. It is always necessary to distinguish clearly between exterior and interior door frames when ordering joinery because the exterior door frames require heart timber, primed joints, and weather grooves.

Solid rebated jambs

Both jambs and head of a solid rebated door frame are machined from $1\frac{1}{2}$ in. timber to the finished shape and size, as shown in *Fig.* 329. The rebate, $\frac{1}{2}$ in. deep and $1\,11/16$ in. wide, is formed to suit the average $1\frac{5}{8}$ in. door.

The shoulder of the rebate provides the stop for the door and also provides the necessary cover to exclude draughts, rain, and light.

The clearance between a door sill and an exterior door should not be much greater than $\frac{1}{16}$ in., but for interior doors an allowance of $\frac{1}{4}$ in. is made when linoleum is to be used on the floor and $\frac{5}{8}$ in. for carpet with

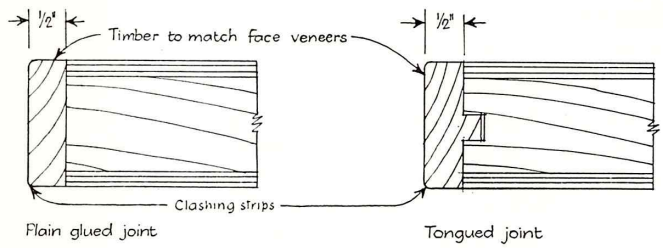
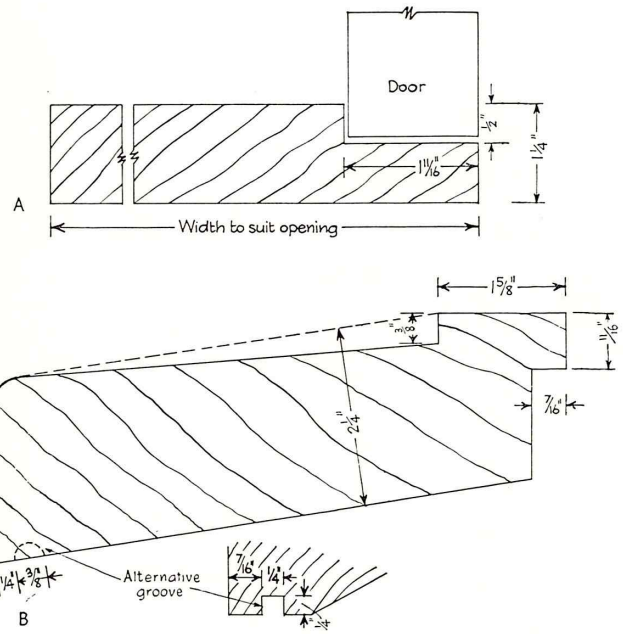


Fig. 328

Two methods of securing clashing strips



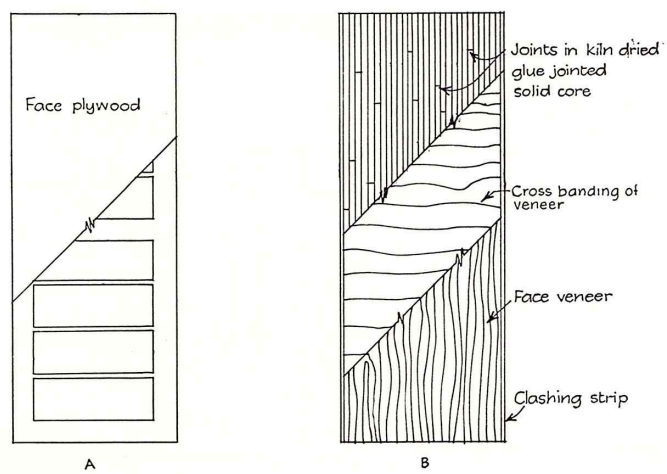


Fig. 327

Flush types of door

(A) *Hollow core* (B) *Solid core*

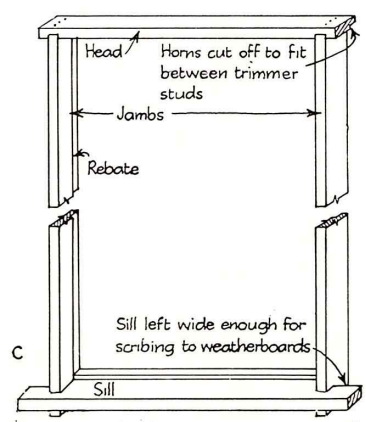


Fig. 329

Members of exterior door frame

(A) *Cross section of door jamb*
(B) *Cross section of door sill*
(C) *Assembled door frame*

underfelt. To avoid draughts it is necessary to keep the bottom clearance to a minimum.

Joints in door frames (*Fig.* 330)

Jambs are simply housed into the head of a frame to the depth of the rebate and securely nailed. The head of the frame is made longer so that it will project at least 1 in. beyond the jambs (these projections are known as "horns" and should be of sufficient length to fit between the trimmer studs of the door opening).

The joints between the jambs and the sill are made by checking out the thick portion of each jamb to the shape of the sill, which is then sawn to a suitable length so that it will fit between the rebates of the jambs. The horns on the sill are left long enough to extend beyond the external facings and should be cut off to show a return equal to the distance that the sill projects in front of the facings (*Fig.* 331).

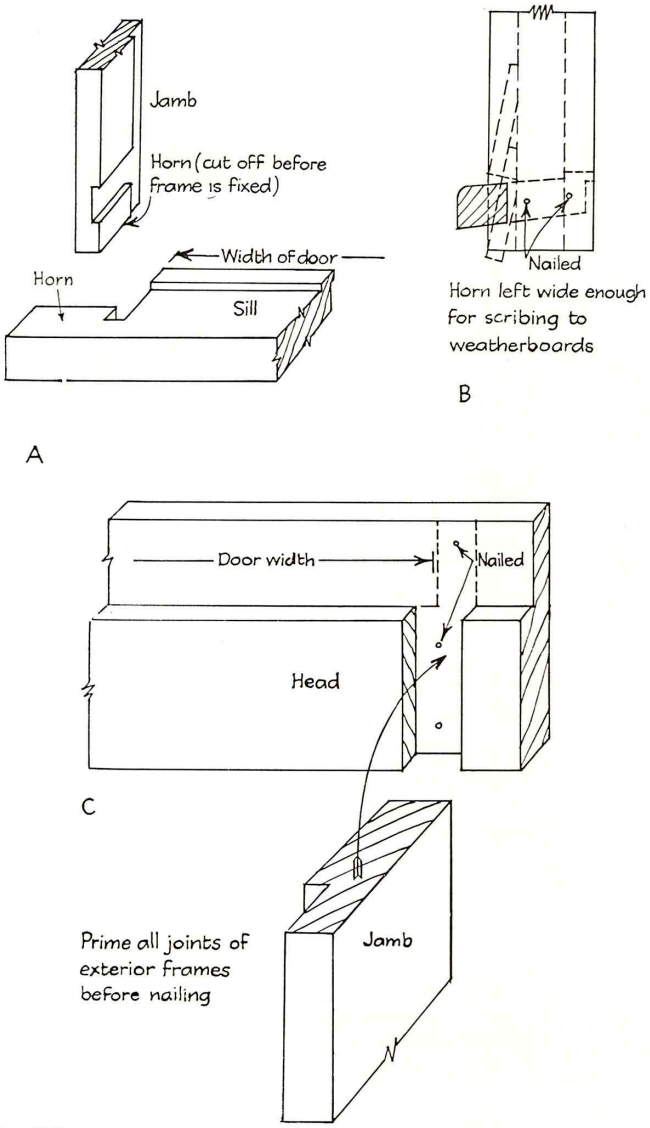


Fig. 330

Joints of door frame

(A) *Joint between sill and jamb*
(B) *Provision for scribing to weatherboards*
(C) *Joint between door head and jamb*

Width of jambs

The width of door jambs is determined by the thickness of the wall framing together with the combined thickness of the wall coverings on each side of the wall; therefore an interior door jamb would be $4\frac{1}{2}$ in. wide in a wall with framing gauged to $3\frac{3}{4}$ in. and with $\frac{3}{8}$ in. fibrous plaster on each side of the wall.

Jambs are usually made $\frac{1}{4}$ in. wider than required and the edges bevelled slightly (undershot) so that the facings fit.

Jambs for windows and doors in exterior walls vary in width according to the type of wall construction (*Fig.* 332).

Plain jambs with planted stops

Jambs for interior doors are sometimes made out of 1 in. timber (finishing $1\frac{3}{16}$ in.) with planted stops $\frac{1}{2}$ in. thick (*Fig.* 333).

The jambs are housed $\frac{1}{4}$ in. deep into the head and nailed, and the stops are fitted after the door is hung. The head stop is fitted first – then the jamb stops are cut to fit. The stops are tapped into position to fit the door with the necessary clearance, and nailed to the jambs with $1\frac{1}{4}$ in. brads.

Weathering devices for exterior door frames (*Figs.* 334 and 335)

Because exterior doors normally open inwards and do not have "double sunk" or steeply angled sills, they are not as weatherproof as casement windows. For these reasons exterior doors are protected as much as possible from driving rain by porches, hoods, or canopies. In addition, the following devices are employed:

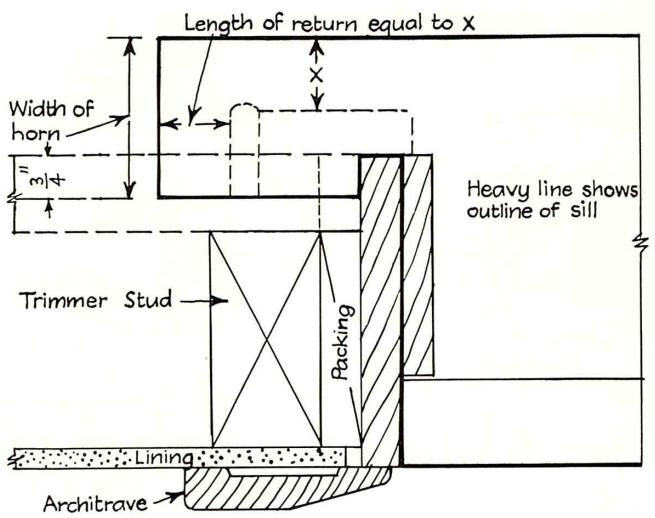


Fig. 331

Return of sill of door frame in exterior wall

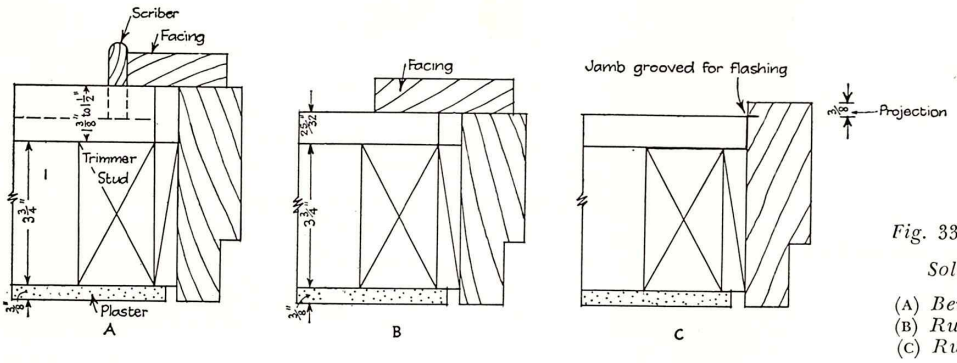


Fig. 332

Solid rebated jambs for exterior walls

(A) *Bevel-back weatherboards*
(B) *Rusticated weatherboards*
(C) *Rusticated weatherboards without facings*

(1) The rebates of the jambs have weather grooves ("throatings").

(2) A weather groove may be run at the bottom of the door.

(3) An angled weather strip may be fitted on the outside face of the door.

(Weather grooves are placed where they will break the capillary effect between two surfaces nearly in contact.)

Weather bars in wood or metal which project above the sill are sometimes fitted but their use is avoided if possible because they are liable to cause tripping.

French doors leading on to balconies, in exposed situations, have sills and jambs similar to casement window frames.

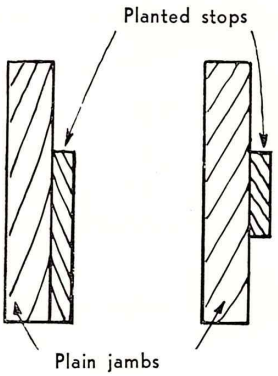


Fig. 333

Plain jambs (with planted stops) for interior walls

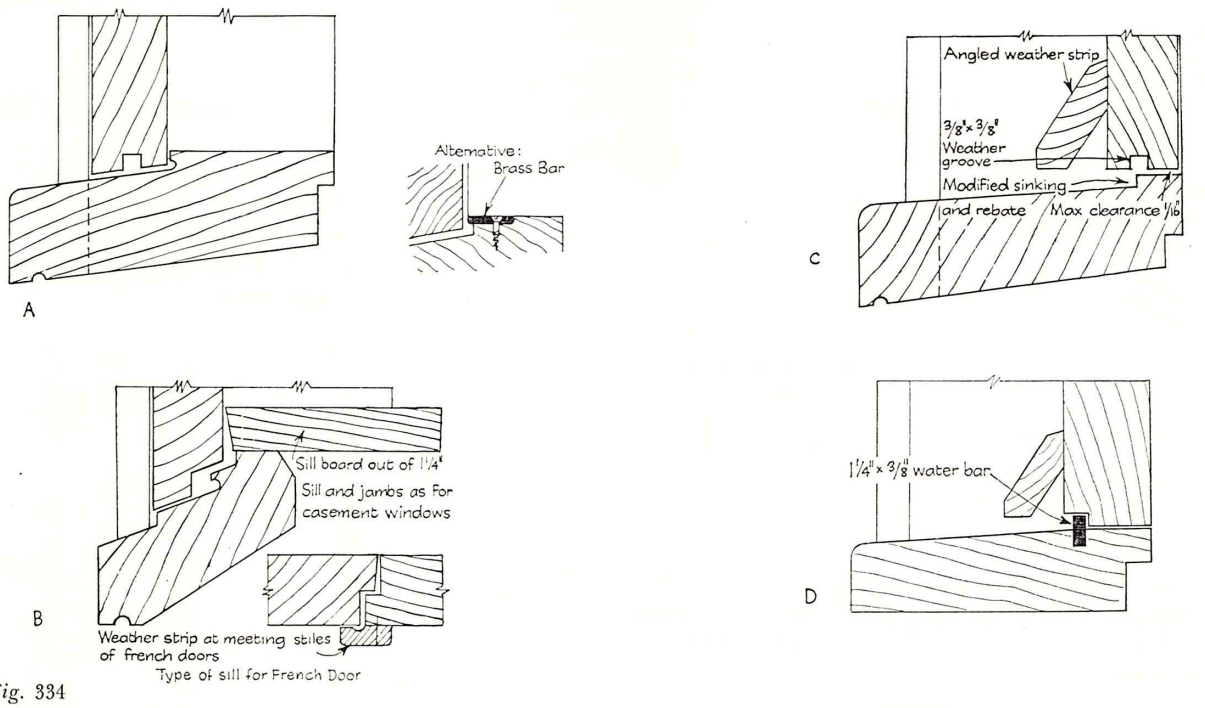


Fig. 334

Weathering devices on doors and door sills in an exterior position

(A) *Weathering devices for doors opening outwards*
(B) *Weathering devices for French doors opening in exposed positions*
(C) *Weathering devices on doors opening inwards*
(D) *Alternative weathering devices on doors opening inwards*

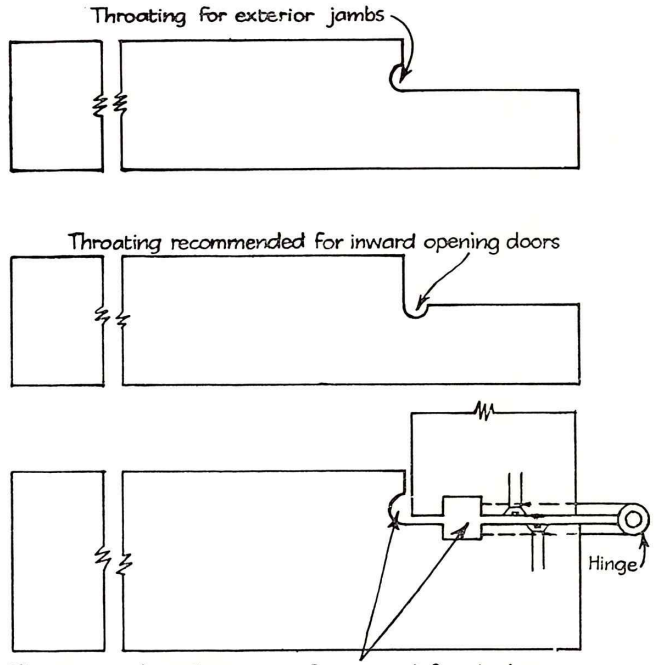

Throating for exterior jambs
Throating recommended for inward opening doors
Hinge
Throating and weather grooves for exposed french doors
(as for Casement jamb)

Fig. 335

Weather grooves on door and window frame jambs in exterior positions

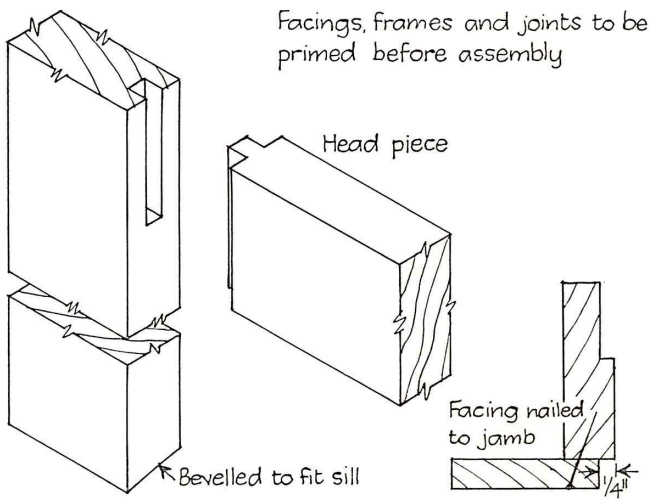


Fig. 336

Method of jointing facings

Facings

Most exterior door frames have facings jointed in the same manner as window facings and set back $\frac{1}{4}$ in. from the edges of the jambs. *Fig.* 336 shows one method of making the joints.

Dimensions of door frames and doors

Doors of stock sizes may be either under or over that particular size, and so it is necessary to measure each door and to make the door frame to suit.

Fixing door jambs

When a door frame is made it should have either one or two temporary braces tacked across the top corners to keep it square and if an interior frame a temporary spreader fixed near the lower ends of the jambs to hold them parallel (*Fig.* 337).

Before the jambs are cut to length (i.e., height of door plus the amount of clearance to be allowed under it) the floor at the doorway must be checked for level to determine if there should be any difference in the lengths of the jambs so that the head of the frame may be perfectly level.

The head of the frame is cut for a sliding fit between trimmer studs. Packing pieces or folding wedges are fixed behind hinge positions and at intermediate places as required. Packings are made to line with a straight edge plumbed in position, and, in nailing, the nail should be kept clear of hinge positions. If folding wedges are used, they are inserted between the jamb and the trimmer stud and the jamb is plumbed and straightened by a plumb rule or straight edge and level.

When the frame is placed in the opening, the edge of the hanging jamb is kept flush with the surface of the wall sheathing. After plumbing and straightening, it is secured to the stud with 3 in. nails driven through the packing pieces or folding wedges. After the door has been hung, the other jamb is arranged with packing pieces or folding wedges between the jamb and the trimmer stud. This jamb is then adjusted to the edge of the door with a clearance of about $\frac{1}{16}$ in. between the door and the jamb (*Fig.* 338).

Fitting and hanging a door

The fitting and hanging of a door varies slightly depending upon:

(1) Whether the jamb is plain or rebated.

(2) Whether the jambs have been fitted to the door while the door frame was being assembled.

(3) Whether the door has to be fitted and hung to a frame which has one loose jamb.

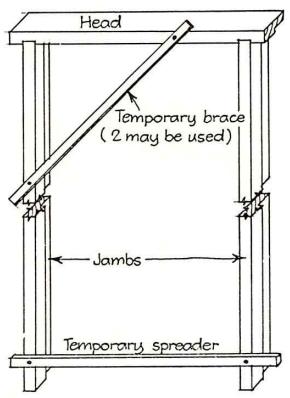


Fig. 337

Interior door frame

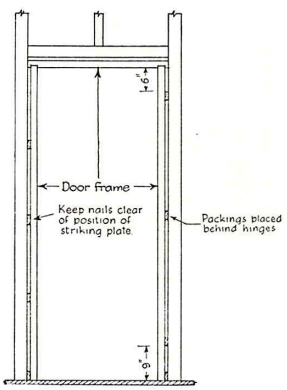


Fig. 338

Position of door frame between trimmer studs

(4) Whether the door has to be fitted and hung to a door frame which has both jambs secured in position in the opening.

We shall deal only with the third case as this is the one most commonly met.

First of all a floor block must be made for holding the door vertically on edge while the stiles are being dressed and the hinges fitted. A floor block comprises a piece of 4 in. x 2 in. about 2 ft. long with a check taken out of one edge for the door and a wedge (*Fig.* 339).

Door frames should have been made with clearance of at least $\frac{1}{16}$ in. allowed over the actual dimensions of doors so that a door may be placed in the frame opening without a lot of fitting.

Nowadays doors are squared off to a length, but should the horns on the ends of the stiles remain, they are cut off and the end grain lightly dressed. The hanging edge of the door stile should be shot straight and square with a try plane, and the edge of the closing stile shot straight, but bevelled slightly so that the stile will not clash against the jamb when the door is closed. Arrises should be removed and the edges glasspapered to a smooth finish.

Place the door in the frame with a wedge or chisel raising it to its correct position; and then check the fit of the hanging stile and also the top of the door. If this is correct, measure the distance from the bottom of the door to the floor. Should this be insufficient for the floor covering to be used, wing compasses, open to the required amount, are employed to mark a line on the door parallel with the floor. Hinge positions are now marked on door and jamb.

Marking position of hinges

A door is usually hinged with $1\frac{1}{2}$ pairs of 4 in. butt hinges. One hinge is placed clear of the top and another clear of the bottom rail and the third centrally between the other two.

The following procedure is adopted for the marking of the hinge positions on the door and frame. Either of the following methods may be used:

(1) The hinges are fixed on the edge of the door (while it is in the door block) and then the door is raised into its correct position between the jambs for the hinge positions to be marked on the jamb.

(2) The door is placed in its correct position between the jambs and a hinge is in turn held at each hinge location and their positions are marked on both the jamb and the door stile (*Fig.* 340). After the door has been removed the marks are squared on the edge of the door and the rebate of the jamb.

Gauging width and depth of hinge housings

Hinges are always housed flush on both the door and the jamb. A butt gauge is most useful for gauging the width of the hinge housing, particularly on solid rebated jambs, because, when properly used, this gauge provides

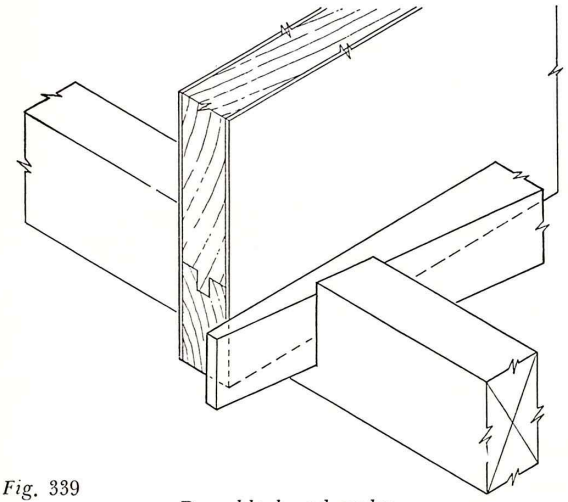


Fig. 339

Door block and wedge

a clearance that prevents the inside of the door binding against the door stop. As shown in *Fig.* 341, place a hinge on the edge of the door, with the bend in the hinge flap just clear of the outside face of the door stile, so that the hinge flap lies flat on the edge of the door; then, from the inside of the door, set the gauge to the distance shown. Gauge a line at each hinge position.

The inside edge of the hinge housing is marked on the jamb with the spur on the *side* of the gauge which is connected to the spur previously used. The depth of each hinge housing is gauged to the thickness of a hinge flap. The third spur on the butt gauge is used for this purpose. When planted stops are to be fixed, the width of the hinge housings may be set out with an ordinary marking gauge. As the stops are fixed, after the door has been hung, provision for a clearance is not necessary when the hinge positions are marked.

Housing and fixing of hinges

The hinge housings are usually cut with a butt chisel, which is nicely balanced and particularly suited for this work.

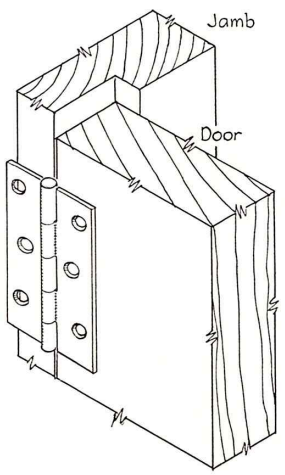


Fig. 340

Method of marking hinge position on door and jamb

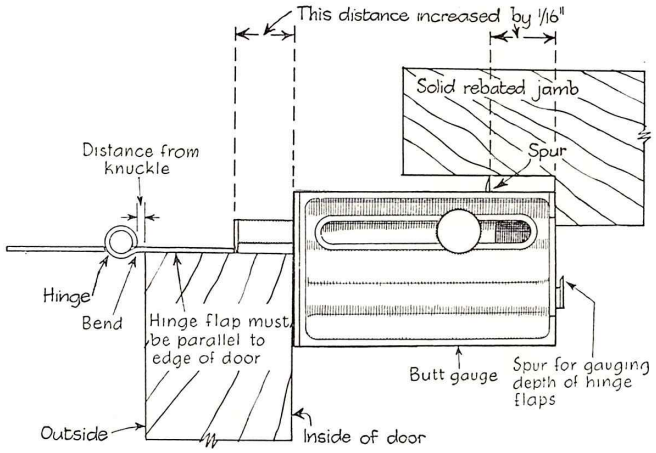


Fig. 341

Use of butt gauge for marking hinge positions on door edge and jamb

Before the hinges are fixed the sharp edges (arrises) of the door should be lightly rounded with a smoothing plane and finished smooth with glasspaper if this has not already been done.

To hinge the door to the frame, the door is held up on wedges at right angles to the wall and, when the top hinge has been secured with one screw, the others may be similarly fixed. If the clearance between the door and the jamb is correct the remaining screws are inserted. The loose jamb should now be fixed in position and the door shut to test the clearance.

Hinges for doors

Most door hinges have loose pins which allow each hinge flap to be fitted separately on the door and jamb. Possibly their greatest advantage is that a door may be speedily removed and replaced. The highest pin hinge on a door should be located so that the pin may be removed.

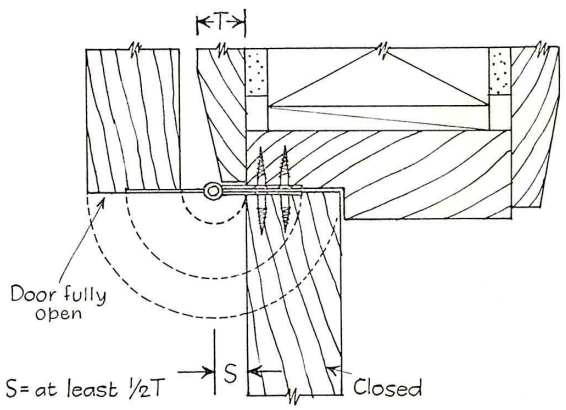


Fig. 342

Position of hinge in relation to the distance that a door will open back

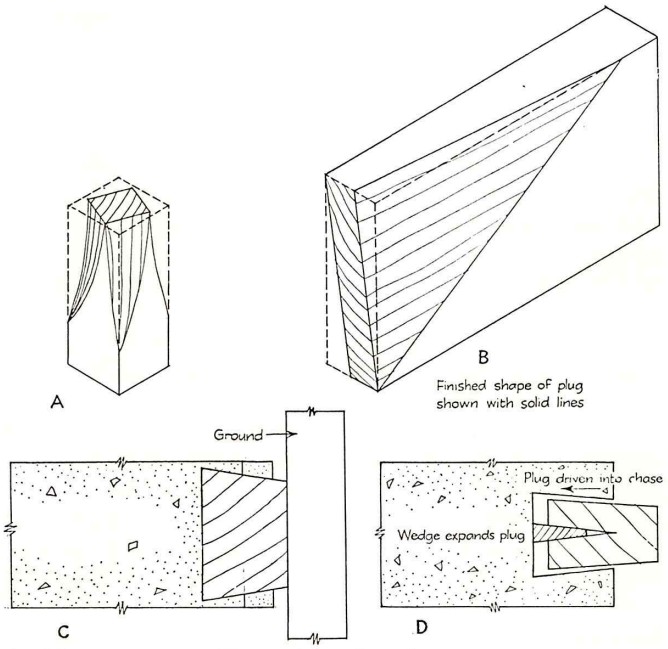


Fig. 343 *Types of wooden plugs*

(A) *Skew-cut plug*
(B) *Skew-cut plug for brickwork*
(C) *Dovetailed-shaped plug in concrete*
(D) *Dovetailed-shaped plug with expanding wedge*

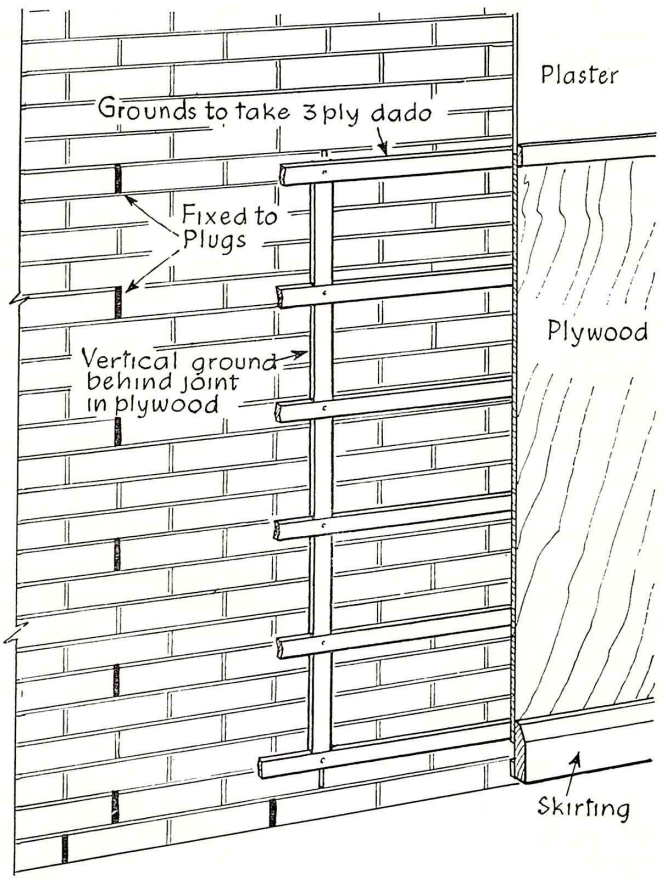


Fig. 344 *Wooden plugs and grounds for brickwork*

Butt hinges are usual but when a door must be opened through 180°, a broad type of hinge is used so that the door, in opening, will clear the architrave.

Fig. 342 shows that the distance S from the surface of the door should not be less than half the distance T (the thickness of the architrave) so that the fully opened door will clear the architrave.

Fixing joinery to brickwork and concrete

Various items of joinery are secured to wooden plugs fixed at appropriate positions on a wall and around window and door openings. *Fig.* 343 shows the various types of wooden plugs for use in concrete or brickwork.

In concrete work, dovetail-shaped plugs are cast in the concrete or holes are drilled to take plugs; in brickwork the plugs are driven into holes made in the vertical joints of the brickwork. Such plugs should be of durable timber and dry; otherwise they will become loose.

When sheets of wallboard or plaster are to be fixed to a wall, the usual plan is to fix wooden battens called grounds, both vertically and horizontally to wall plugs built into the walls, or to plugs driven into the joints between the bricks. The grounds around window and door openings are framed at the angles, and, in general, arranged to provide a solid foundation for the wallboard or plaster sheets, and, in fact, provide solid nailing where finished woodwork has to be secured to the wall *(Fig.* 344).

In brick construction window and door frames are accurately placed in position, and, after being braced, the brickwork is built against them. The frames are held secure in cavity walls by cleats which fit into the cavity, and at other times by galvanised straps secured to the frames, and built into the brickwork.

It is often necessary to drill holes in brickwork or concrete when fixing joinery fittings. Many kinds of drills are available for boring such holes, as also are the devices or plugs for fitting into the holes. One type consists of a plug of twisted fibre which is spread by the nail or screw inserted in it, and thus holds secure.

The construction pistol, which employs an explosive charge, is extensively used nowadays for driving pins, threaded studs and other such devices into walls of concrete or brickwork for the fixing of joinery.

Questions on Chapter 10

(1) A lounge is 16 ft. 3 in. by 12 ft. 5 in. The window for this room is of minimum size and part of this window is made to open. If the window is 4 ft. 6 in. high, state:
   (a) The width of the window.
   (b) The glass area that must open for the ventilation of the room.

(2) Describe how you would fit and secure a three-light casement window frame in the wall of a two-storey weatherboarded house.

(3) Sketch and describe the arrangements necessary to make a window frame weatherproof in a house sheathed with stucco.

(4) Sketch a horizontal section through an internal door and frame in a partition sheathed with fibrous plaster. Show dimensions and name the various parts.

(5) Sketch a vertical section through an external door and frame in a weatherboarded wall:
   (a) In a porch.
   (b) On an external wall.

(6) (a) State the moisture content that timber is seasoned for:
   (i) Exterior joinery.
   (ii) Interior joinery.
   (b) Describe the various kinds of louvres, where they are used, and state whether a louvre has any advantages over the casement sash.

(7) What kind and size of door would you recommend for the front, rear, and interior of the average type of dwelling?

(8) Briefly describe with sketches how you would make a frame and hang the door for an opening in a partition wall of 4 in. framing with $\frac{3}{8}$ in. fibrous plaster wallboard on both sides of the partition. Assume that a solid rebated frame is to be used and a flush door is to be hung.

(9) Describe the provisions made for securing joinery to:
   (a) Concrete walls.
   (b) Brick walls.
   What would be the position if the normal fixing arrangements had been omitted during the construction of the walls?

(10) Give the dimensions of the stock sizes of:
   (a) The front door of a house.
   (b) An interior door.
   (c) A wardrobe door.

(11) Show by sketches the different methods of flashing the head of a casement sash in bevelled-back weatherboard construction.

Calculations

(1) How many cubic feet of earth are required to fill to a depth of 9 in. twelve window boxes, the internal dimensions of which are 4 ft. 2 in. by 8 in.?

(2) A room 14 ft. 6 in. long and 12 ft. 6 in. wide and 8 ft. high is to be panelled with plywood sold in 8 ft. x 3 ft. sheets. How many sheets will have to be bought and what area of wood will be wasted? Allow 50 sq. ft. for windows and a door.

(3) A rectangular vat is 3 ft. by 2 ft. and the depth is 10 in. Find the capacity in gallons and the weight of water that it will hold.

(4) The flow of water through a 2 in. circular pipe is at a rate of 20 ft. per second. How many gallons of water will be delivered by the pipe in 5 minutes? (1 cu. ft. $= 6\frac{1}{4}$ gal.)

(5) A flat roof 48 ft. x 32 ft. is to be covered with bituminous felt $\frac{1}{12}$ in. thick. Allowing 5 per cent for joints, find the volume of the felt required.

Chapter 11

INTERIOR WALL COVERINGS

Many kinds of interior wall linings are available and the choice of a particular lining will depend upon whether it has such qualities as strength, stability, fire resistance, and general durability. Other points for consideration are whether the surface of the lining is suitable for papering, painting, enamelling, or similar treatment.

Those linings most frequently used include fibrous plaster boards, plaster-cored wallboards and wood fibre boards. Plywoods are used for panelling in better class work and are gaining in popularity as wall linings generally.

Fibrous plaster sheets

Fibrous plaster sheets are made of plaster of paris with fibres of flax or sisal to reinforce them. Sheets are usually $\frac{3}{8}$ in. thick and on most occasions are made in sizes to the order of the builder.

Fibrous plaster sheets are used for lining walls and ceilings to provide a smooth surface suitable for painting or papering. Where desired, ceiling sheets may be obtained with the decorative surface pattern of the glass on which they have been cast.

On an external corner a plaster finish is easily broken or damaged and so a vertical wooden strip should be fixed flush with the surfaces at such corners.

Fibrous plaster may be used in all internal positions in a house except in the vicinity of showers in bathrooms, where continual drenching with water will eventually cause the disintegration of the sheets.

On curved work, flat sheets may be bent to the shape of the framing, but for curves of radius less than 2 ft. a specially cast sheet is to be preferred.

To improve acoustics and sound insulation special tiles of fibrous plaster or other materials may be used where necessary.

Fibrous plaster may be moulded into any decorative form including cornices, mouldings, and other architectural features.

Fixing and stopping joints

All sheets should be fixed with spaces of from $\frac{1}{8}$ in. to $\frac{1}{4}$ in. between sheets and nailed with 1 in. galvanised, flat-head clouts spaced at about 5 in. centres $\frac{1}{2}$ in. from the edges, and at 18 in. centres elsewhere. All the heads of clouts are punched below the surface and later the holes, as well as the spaces between the sheets, are stopped with plaster of paris.

Wadded joints

On ceilings, sheets are usually joined on a joist or a row of dwangs between joists, but a wadded joint is sometimes used in good-class work and in districts subject to earthquakes. Such a joint is made by joining the sheets *between* the joists or rows of dwangs, and applying a backing over the joint of scrim or teased fibre dipped in liquid plaster of paris. A liberal application of plaster reinforces the joint. Dwangs are often placed at right angles to a wadded joint. Sheets may be nailed to the dwang or a strap of fibre taken over the dwang from the back of the sheet where it is secured with plaster.

Plaster-cored wallboard

This wallboard consists of a stiff paper casing containing an unreinforced filling of plaster of Paris and pumice. The paper casing adheres to the filling and this makes a strong, resilient sheet of wallboard.

Sheets are $\frac{3}{8}$ in. thick and are in 3 ft. and 4 ft. widths, to suit fixing centres of 18 in. and 24 in. and in lengths of from 6 ft. to 10 ft.

Plaster-cored boards are used for covering walls and ceilings, the sheets being fixed with spaces of about $\frac{1}{8}$ in. between the sheets. All nail holes and joints between the sheets are stopped with plaster of paris.

Cutting to shape

The sheets may be sawn to shape but the quickest and cleanest method is to cut the paper. A straight edge should be used as a guide, and a cut made with a sharp knife, chisel, or a razor blade held in a frame, the board then being folded away from the cut. It will be found that the plaster filling will break along the line of the cut. The sheet is then folded back so that a crease is formed in the paper on the back of the sheet, along which the final cut is made. A ragged edge should be avoided as such edges swell when the joints are stopped and foul the plasterer's float.

A method of preparing a sheet for an internal corner is to cut the paper on one side of the sheet, break the sheet, and then fold it into a corner, leaving the paper intact on the face of the sheet. Such a joint cannot be recommended under all circumstances but is quite satisfactory when used for the corner of a cupboard or wardrobe.

For short-radius curves sheets must be saturated with water and left to dry on forms made to the desired shape. Sometimes a sheet is saturated and left leaning against a wall at an angle so that the sheet will gradually sag into the shape required.

When it is necessary to bend a sheet around framing to the shape of a tight curve, a number of parallel cuts are made on either the back or the front of the sheet as circumstances demand.

Sheets are fixed by nailing over the surface of the sheet with $1\frac{1}{4}$ in. flat-head nails spaced at about 9 in. centres and at intervals of from 4 in. to 5 in. half an inch from the edges. When nailing, the last blow of the hammer should sink the head of the nail below the surface of the board and make an indentation without breaking the surface. On no account should the nail head be punched. Galvanised or cadmium-plated nails are used because the galvanising or cadmium plating resists the corrosive action of the plaster of paris.

Wood fibre boards

Wood fibre boards are of two distinct types, hardboards and softboards. Hardboards are dense in structure and have a hard, smooth surface finish, but softboards have the opposite properties in that they are open textured and comparatively soft, and have roughened surfaces. Softboards have a thickness of $\frac{1}{2}$ in. and are available in widths of 4 ft. and 4 ft. 6 in. and range in length from 6 ft. to 10 ft.

Mouldings for cornices, friezes, and joints are made from the softboard material in a variety of patterns, thus enabling a trim to be made of the same material as the wallboard.

Conditioning

Wood fibre lining boards expand and contract with changes in the humidity of the surrounding air. Consequently they move to a certain extent and therefore should be cured or conditioned before being fixed.

An oven-dry board direct from the factory will absorb moisture, and sheets stored in damp situations will almost certainly have too high a moisture content; so it is always advisable to condition the sheets on the job by standing them on edge about the walls for about twenty-four hours, so that their moisture content will agree with that of the surrounding air. This conditioning process cannot be carried out until the job has been "closed in" and the work is comparatively dry.

Use of softboards

Softboards may be used for ceiling and wall linings in all parts of a dwelling, except where there is likely to be undue wear or frequent drenchings of water, as in shower rooms or kitchens and bathrooms, which require a smooth impervious surface for painting.

Owing to its tendency to move, softboard is not recommended as a base for wallpaper or for flush finishes, unless the joints between the sheets are reinforced by a 2 in. strip of linen or stiff paper. In addition, heavily textured wallpaper should be used, as it is capable of stretching slightly under the action of the wallboard.

Because softboards move to a certain extent, it is impossible to make a satisfactory flush joint between the sheets. The joints are either covered with mouldings or left exposed with the edges of the sheets bevelled to form a V joint.

Cutting to shape

Sheets are cut into pieces of required size with a panel or other fine-toothed saw and the edges trimmed and bevelled when necessary with a special tool known as a vee jointer.

Fixing sheets

When joints are covered with a moulding an expansion allowance of $\frac{1}{8}$ in. is provided for around the edges of sheets, but on exposed joints the edges of the sheets are either lightly butted or a slight clearance allowed. Sheets should never be sprung into position because subsequent movement will cause them to buckle.

In fixing softboards, $1\frac{1}{4}$ in. flat-headed galvanised nails are spaced at 4 in. to 6 in. intervals, $\frac{1}{2}$ in. from the edges, and at about 9 in. intervals on intermediate dwangs, studs, and joists. Nail heads are driven slightly below the surface of the sheet, but on no account should hammer marks be left, the filling of the hole being confined to the space above the nail head only.

Softboard does not have a corrosive effect on nails, but stopping mixtures contain plaster of paris which rusts the heads of nails not galvanised.

In good-class work softboards are often fixed with $1\frac{1}{2}$ in. panel pins spaced at the same intervals as recommended for galvanised nails. The panel pins are driven at an angle in pairs so that they cross, and although they do not hold the sheet as securely as flat-headed nails, they have the advantage of leaving an inconspicuous hole which does not require filling.

Curved work

Softboard may be bent around the curves of a radius of about 2 ft. Should difficulty be experienced, wetting or saw cuts on the back of a sheet will assist. The method of allowing a sheet to sag to the shape of a mould is often used, but for very difficult curves several pieces of softboard may be glued together and then machined to shape, or 1 ft. strips of board may be split to half the thickness and the curve built up of thin layers glued together.

Hardboard

Hardboard is a hard, tough wood fibre lining board designed for hard wear. Sheets manufactured in New Zealand are 8 ft. x 4 ft. and are available in thicknesses of $\frac{1}{8}$ in., $\frac{3}{16}$ in., or $\frac{1}{4}$ in. Hardboard imported from other countries is in 9 ft., 10 ft., and 12 ft. lengths.

The colour of hardboard is a pleasant shade of brown with a smooth hard surface which is suitable for either paint or enamel finishes on walls and ceilings.

Oil-tempered hardboard

Oil-tempered hardboard is a hardboard that has an extremely hard and moisture-resistant surface that will withstand weather conditions in exterior situations provided it is protected by a good-quality paint.

Conditioning of hardboards

As hardboards are made of wood fibre they have the same properties as timber and softboard, in that they will absorb moisture and expand and will shrink when moisture is lost.

The conditioning process is done by wetting the backs of boards with a brush dipped in water, and stacking for 24 hours before use. Hardboard manufactured in New Zealand is conditioned to suit average internal requirements before it leaves the factory, but other makes often carry instructions for the user to wet the back of the board before erection to ensure that buckling does not occur.

For very damp situations it is advisable to condition the boards further by standing them for a period of twenty-four hours in the situation where they will be fixed.

Oil-tempered hardboard needs a longer period of conditioning on account of its high resistance to moisture.

Fitting and joints

Hardboard may be sawn or planed with the usual woodworking tools and secured with nails or with an adhesive.

Joints should never be flush finished; the edges are either bevelled or rounded, or covered with various kinds of wooden or special metal mouldings. When wooden mouldings are used, little nailing on the edges is necessary thus giving greater freedom for the boards to move. When strips or mouldings are used to cover the joints, the sheets are usually secured with flat-head nails, and with galvanised flat-head nails in such rooms as bathrooms and kitchens where high humidity is frequent, but when joints are exposed, the sheets are secured with 1 in. panel pins driven on the skew to increase their holding power. Panel pins are spaced at intervals of 4 in. to 6 in. half an inch from the edges, and at intervals of 9 in. over the surface of the sheet. The secret of securing hardboard is to commence nailing at the centre of a sheet and work to the edges in order to avoid buckling.

Curved work

Hardboard may be bent with safety to as small a radius as 18 in. without special treatment, but for smaller curves bending is assisted by immersion of the sheet in hot water or the application of hot wet cloths. Shallow knife cuts on the back of the sheet assist bending. Manufacturers can bend hardboard with special equipment to a radius as small as 2 in.

Framing and fixing procedure

Framing requirements for wallboards depend to a large extent on the particular width of board being used, but generally the studs and joists are spaced at 18 in. centres with wall dwangs at 27 in. centres and ceiling dwangs at intervals of 3 ft.

Framing timbers should be well seasoned before linings are fixed; otherwise the shrinkage and consequent movement of the timbers may result in open joints and bulged sheets.

When light fittings are close to wall and ceiling surfaces finished with a high gloss, extra care must be taken in the framing so that the surfaces of the sheets will be perfectly flat; otherwise any irregularities in either the framing or the sheets will be revealed by shadows when the lights are on.

Before the lining is fixed the following procedure should be followed:

(1) Check the whole of the framing for straightness, and for line.

Remedy omission of any dwangs, especially around fittings and built-in furniture.

(2) See that the plumber, electrician, or other contractors have completed their work. Mark the positions of the plumber's pipes so that they may not be pierced with nails during the fixing of the wallboard.

(3) Mark the positions of the studs and ceiling joists so that they may be easily found during the fixing process and later during finishing work.

It is usual to fix the linings on the ceilings before those on the walls as trestles and planks can be damaging to wall linings, and in most circumstances unlined walls provide ledges for resting scaffold planks.

When fixing wallboards in panels make certain that the sheets are kept parallel with the corners of the room. After lifting a sheet into its position, press it hard against the framing and then secure the centre, before the sides, and continue nailing from the centre outwards.

Nails that fail to pierce the framing should be withdrawn because they may later work out and disfigure the finished surface.

A thorough job of nailing should be made about window and door openings as cracks are able to develop here as a result of the drying of the timber frame.

Questions on Chapter 11

(1) (a) Name the internal lining materials that are used for walls and ceilings in the modern home.
(b) List those kinds of lining most suitable as a base for wallpaper and give your reasons.
(c) What kind of lining would you use on the walls of a shower room, and why would you use it?

(2) Why is it sometimes necessary to "condition" wood fibre boards and how is the process carried out? Why does oil-tempered hardboard require a longer period of conditioning?

(3) On most occasions joints in fibrous plaster sheets on ceilings are made over a solid backing of joists or dwangs. In earthquake areas another kind of joint is often made. Name and describe how such a joint is made.

(4) (a) Describe how you would set about securing sheets of fibrous plaster on a wall.
(b) Explain the method of nailing and state why galvanised nails should be used when fixing fibrous plaster sheets.

(5) (a) State in general terms the distances that studs, joists, and dwangs should be spaced for interior linings.
(b) What are the main points to check before you start fixing sheets of wallboard?

(6) (a) What particular qualities should a reliable wallboard possess?
(b) How are wallboards prepared for a rounded surface of 3 ft. diameter?

(7) The walls and ceiling of the lounge in an old house are to be modernised with fibrous plaster wallboard on the walls, and softboard on the ceiling. The walls are covered with wallpaper on scrim over rough lining and the ceiling is of boards and battens. Explain with brief notes the methods you would use:

(a) To fix and joint the fibrous plaster wallboard for a wallpaper finish.

(b) The fixing and type of joints you would suggest for the softboard.

(c) Sketch and size the type of skirtings you would use and also describe the cornice.

(d) What kind of finish would you make at window and door openings?

Calculations

(1) The trade discount on a three light casement frame and sashes retailing at £20 17s. 6d. was 25 per cent plus $2\frac{1}{4}$ per cent for cash. What was its trade cash price?

(2) A firm employing 350 men reduced its staff by 8 per cent. How many men were then employed?

(3) A house is built for £2,750, allowing a profit to the builder of $22\frac{1}{2}$ per cent on cost. If he cannot sell the house at a price greater than £2,600 what is his percentage profit, if any?

(4) A window which is one-tenth of the floor area of a 12 ft. x 12 ft. room is replaced with a window which is one-eighth of the floor area. What is the percentage increase in the lighting of the room?

(5) A quantity of 15 tons 6 cwt. 84 lb. of reinforcing steel is required for the erection of a building. A quotation of £2 7s. 6d. per cwt. has been obtained for the supply and fabrication of the reinforcement. Calculate the total cost.

Chapter 12

EXTERIOR AND INTERIOR FINISHING

Exterior trim

The finishing work on the outside of a building is known as the exterior trim and includes such processes as the finishing of the eaves and gables, the covering of joints, the fitting of scribers, and, generally, the making of the building, from the carpenter's point of view, weatherproof and complete in every respect so that painting work may be completed.

Eaves

The eaves or overhang of a roof (that portion beyond the walls of a building) shelter the walls from sun and rain. They are classified as boxed, open, and flush eaves.

Boxed eaves

A boxed eave is formed when the ends of the overhanging rafters are "boxed" or hidden with soffit linings and fascia boards. Such eaves may be formed on either the flat or the pitched kind of roof (*Fig.* 345).

Open eaves

As the ends of the rafters are exposed in open eaves, they are dressed and the soffit lining is fixed on the top edges of the rafters (*Fig.* 346).

Flush eaves

A flush eave is adopted mostly on outbuildings. Instead of overhanging, the lower ends of rafters finish flush with the outside of the wall framing; a neat finish being made with a fascia board which supports the spouting (*Fig.* 347).

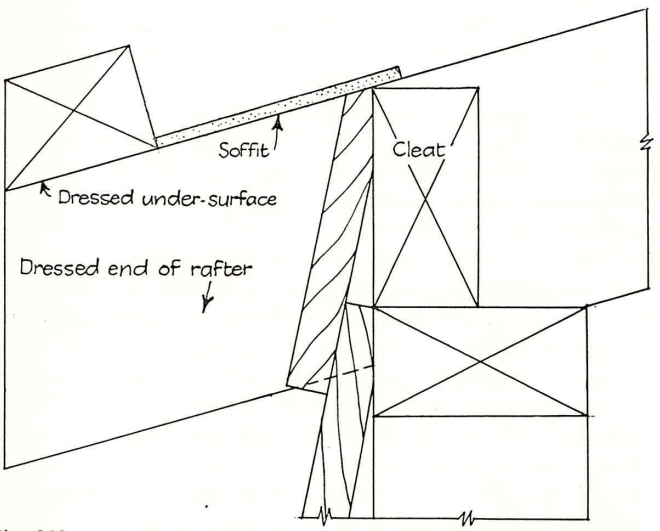


Fig. 346

Open eaves

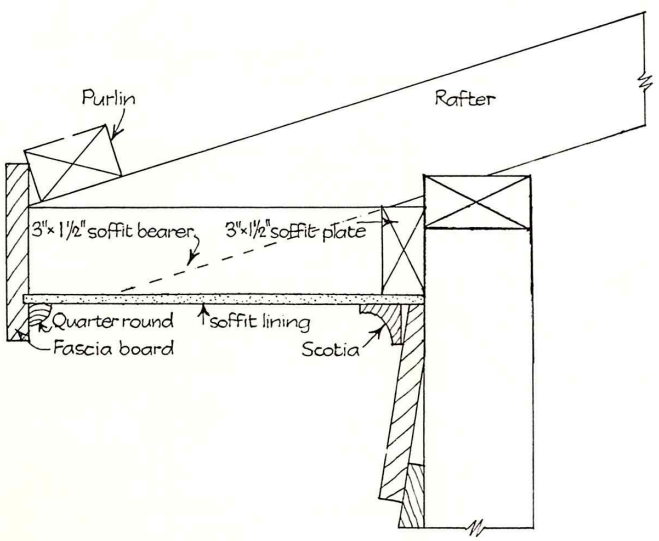


Fig. 345

Boxed eaves

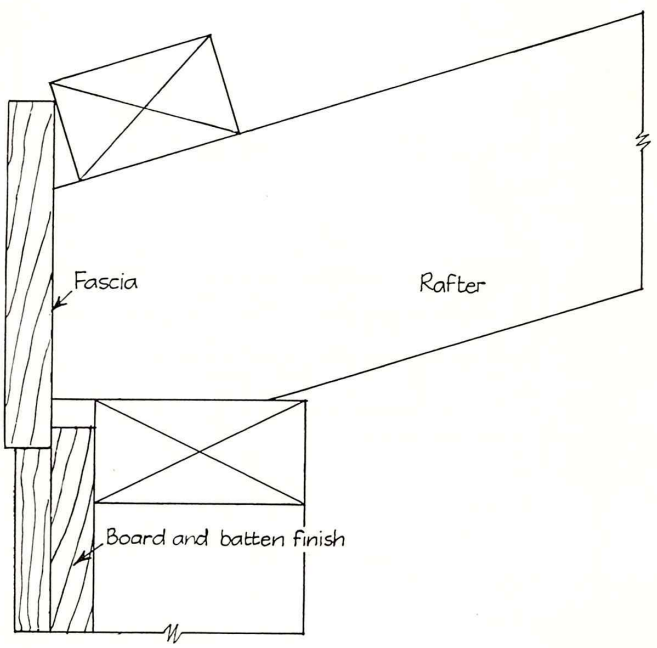


Fig. 347

Flush eaves

Framing for a boxed eave

The framing for the boxed eave shown in *Fig.* 348 comprises a 3 in. x $1\frac{1}{2}$ in. soffit plate that is secured to the wall framing parallel to the top wall plate, with soffit bearers of the same size attached to it and to the ends of rafters. The position of the lower edge of the soffit plate is determined by the amount of overhang specified and the width of fascia board being used. The height of the soffit plate is marked and then a nail is partly driven in the studs at each end of the wall at this height. A line is stretched between these two nails and from it the soffit plate is straightened while being secured. Joints in the plate are made on studs. There are several methods of fixing soffit bearers. One common way is to fix the two end soffit bearers level from the soffit plate, and then fix the intermediate ones to a line stretched between the two end soffit bearers. The horizontal and plumb cuts on the foot of each rafter are made before they have been secured in position.

At an external corner, the soffit framing may be arranged for the soffit lining to be jointed either at an angle of 45°, or square off the wall. First of all, a mitre plumb cut and also a horizontal cut are made on the end of the hip rafter, but in the first case, when the lining is to be jointed under the hip, allowance is made for a piece of timber under the hip so that good bearing is provided for the lining (*Fig.* 349). In the other case the soffit plate is extended from the corners to the back of the fascia board. In both cases the position of the horizontal cut on the hip is found by levelling from the soffit plate.

Fascia Boards

A fascia board varies in width according to the type of roof construction, but for housing work it is usually 5 in. or 6 in. wide, dressed on at least one side and one edge. It should be preferably of heart-quality timber. Joints in fascia boards are always splay cut centrally over the ends of rafters. One method of erecting fascia boards is first to secure those lengths temporarily on both sides of the corners of the soffit and then fix the intermediate ones in position. Before the boards are finally nailed they must be straightened on both the face and lower edge, the process being accomplished by sighting from the extreme ends of the fascia and making adjustments where required. Very little adjustment should be necessary if the soffit bearers have been cut to a line.

Wall finish for gables

The walls of gables may be sheathed with various materials which are frequently of a different kind from those on the main walls of the building. *Fig.* 350 shows some of the finishes that may be employed.

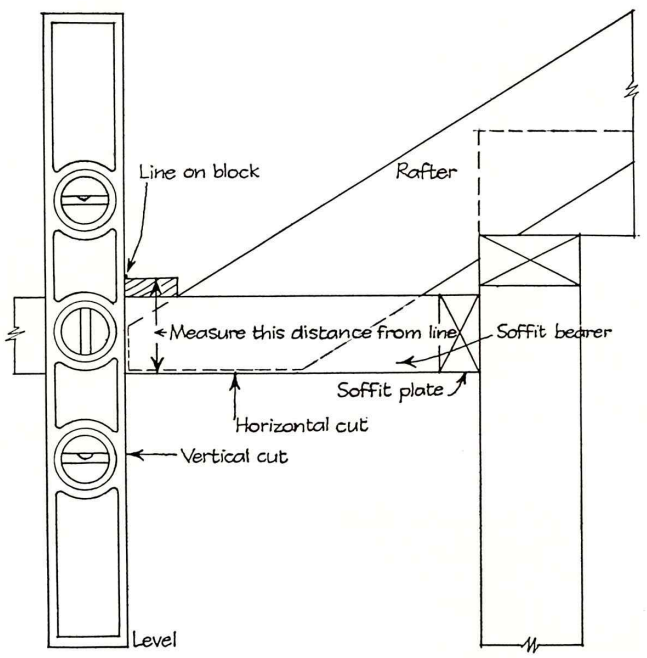


Fig. 348

Framing of boxed eave

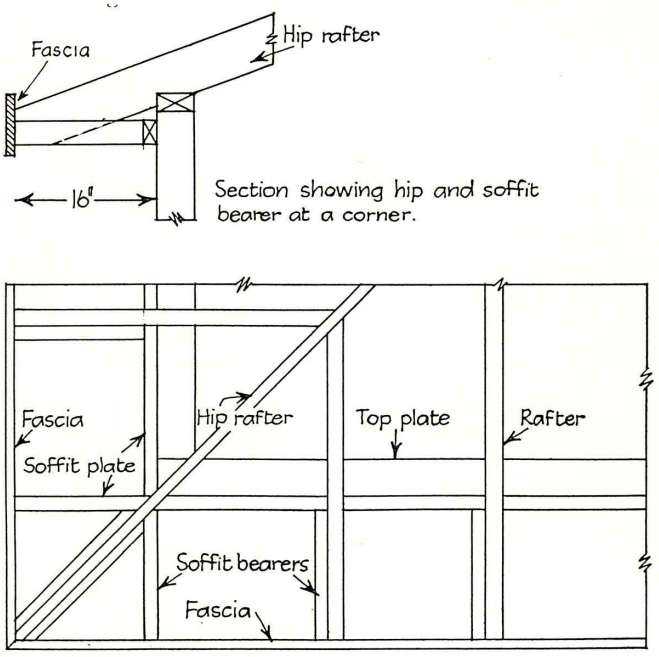


Fig. 349

Plan of framing for boxed eave

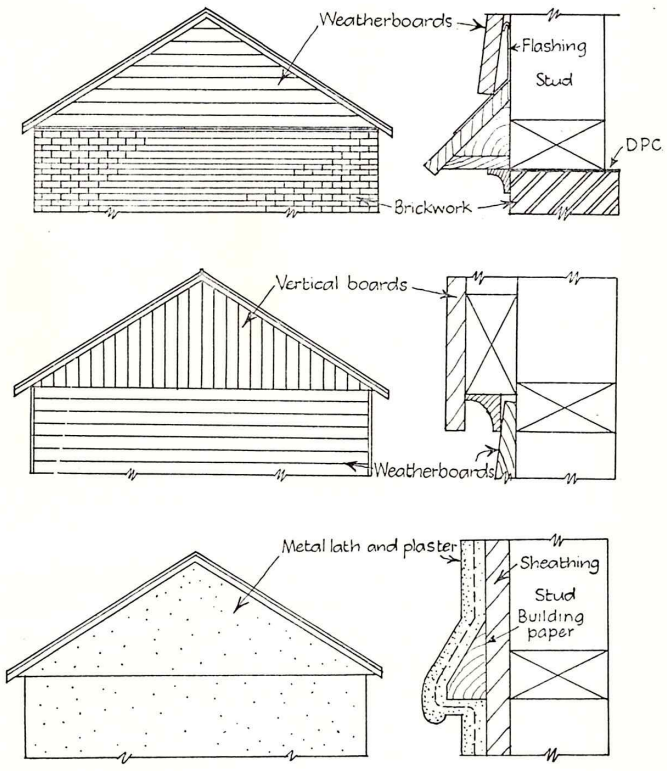


Fig. 350

Gable finishes

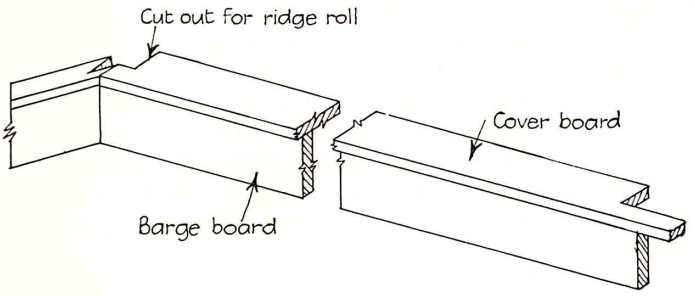


Fig. 351

Barge and cover board

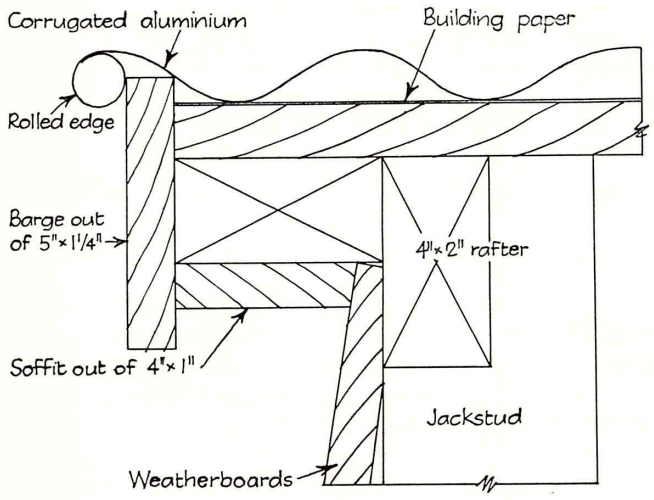


Fig. 352

Rolled edge finish

Barge boards (*Fig.* 351)

The inclined timbers on the gable of a building, known as barge or verge boards are used to cover the ends of the roof timbers. As well as providing a finish, they also help to make the roof weatherproof. They are very much like fascia boards except that they are secured to the outside of the flying rafters of a gable. The top end of a barge board is sawn to the plumb cut of the common rafter. The lower portion provides a cover to the end of the soffit, fascia board and spouting, being finished with either a plumb or a horizontal cut, or a combination of plumb and horizontal cuts.

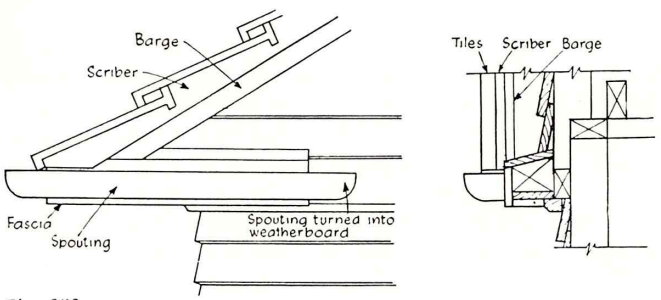


Fig. 353

Typical finish of tiles over gable

Cover boards

Such a board covers the joint between the barge and the roof-covering material. It should be of heart-quality timber cut to the shape shown in *Fig.* 351. When the edge of a tile roof overhangs a barge board, or a corrugated-iron roof is finished with a roll over the edge of a barge, a cover board is not required (*Fig.* 352). One finish of a tiled roof is as shown in *Fig.* 353.

Barge and cover boards moulded in mineral fibre cement are being used to an increased extent, particularly when this material is used also for covering a roof.

Soffit linings

Soffit linings may be of any suitable lining material, such as mineral fibre cement boards, resin-bonded plywood, hardboard, and tongued and grooved V-jointed lining boards.

On most occasions the various kinds of linings are secured with flat-head nails and the joints are either covered with a D-type of moulding or finished with plain vee joints.

Weatherboards may be finished against the soffit in a variety of ways, but the most common methods employed are shown in *Fig.* 354. Frieze boards are not used to any extent these days. In most cases it will be found that a quarter-round or similar moulding provides a neat finish between the fascia and the soffit. Sometimes the edge of the soffit lining is fitted into a groove on the back of the fascia and in these circumstances a moulding is not required.

Soffit linings in a gable should always be secured before the weatherboards below it; otherwise fitting proves most difficult, and often results in an ugly joint.

In flat-roofed houses either ventilation openings are provided in the soffit by means of openings covered with rust-proof wire gauze, spaced battens, or, as is most commonly done, ventilation is obtained by leaving a space of about $\frac{1}{2}$ in. between the back of the fascia and the soffit lining material. When the soffit lining is recessed into a groove on the back of the fascia the ventilation opening is provided between the soffit lining and the wall.

Angle boxes

When weatherboards are not mitred, angle boxes may be fitted over the external corners of the building. An angle box (*Fig.* 355) is made by nailing a 4 in. x 1 in. to a 3 in. x 1 in. piece of timber, and often a bead is run on the fitting edge of the narrower piece. The lower end of an angle box is made flush with the lowest weatherboard and the top is usually fitted against the soffit. When nailing, care should be taken to see that the angle box fits squarely over the corner and is straight and vertical.

Angle stops

Angle stops are not used now to any extent on the exterior corners of residences, but such a finish is often seen on the older types of buildings where the weatherboards are butted against a dressed 4 in. x 2 in. fixed on each corner. For a residence an angle stop may be made from a 3 in. x 3 in. piece of timber rebated to fit over a corner and grooved for metal flashings.

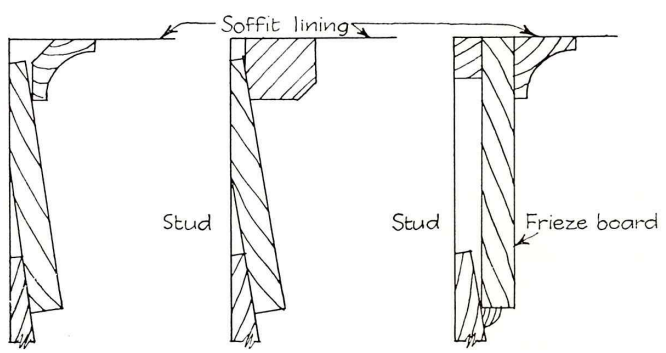


Fig. 354

Finish of weatherboards against soffit

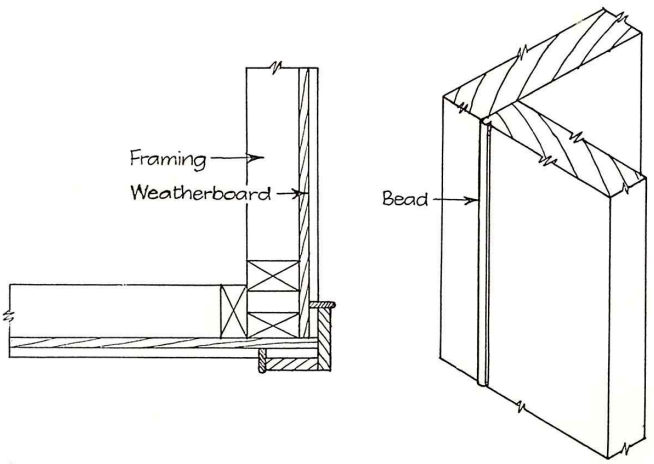


Fig. 355

Angle box

Fitting scribers (*Fig.* 356)

A scriber is a shaped piece of timber used to cover the spaces and also provide a finish between weatherboards and facings of exterior frames of windows and doors, angle boxes, and vertical cover battens.

Usually scribers are of heart-quality timber of the dimensions shown in *Fig.* 356A.

The process of fitting scribers to a window frame is carried out in five steps, as follows:

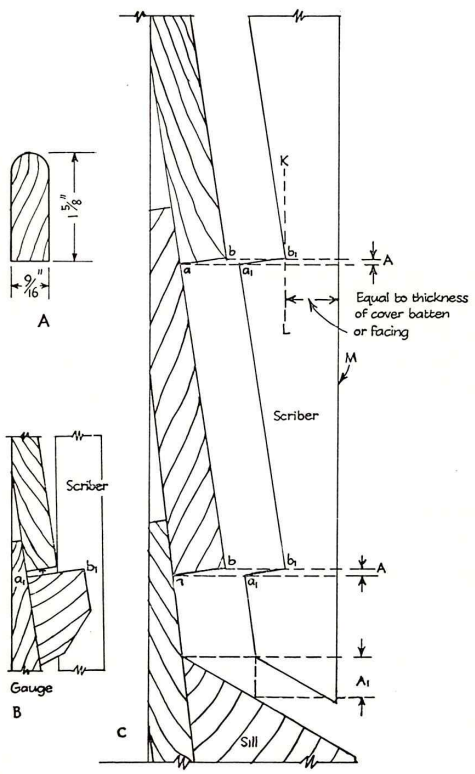


Fig. 356

Method of fitting scribers

(1) Temporarily secure the scriber for purposes of marking.

(2) Mark the scriber with lines corresponding with the front and lower edges of the weatherboards.

(3) Scribe to sill line.

(4) Saw to shape.

(5) Nail in place by fixing to the edge of the facing.

(1) As a scriber is often crooked and the front edges of weatherboards are not always in a straight line, it is advisable to gauge a line on the side of the scriber, about 1 in. from the outside edge, to ensure that the scriber, when fixed, will lie parallel with the facing. Temporarily secure the scriber to the edge of the facing with the gauged line parallel with the front edge of the facing.

(2) It is now necessary to decide whether the finished front edge of the scriber is to be flush, under flush, or slightly raised above the surface of the facing. If it is to be flush, mark a line KL (*Fig.* 356c) parallel to the front edge at a distance equal to the thickness of the facing, and then set wing compasses to the distance bb_1. The compasses are held parallel with the wall, and with one leg of the compasses against the face of each weatherboard, parallel lines are marked on the side of the scriber.

The position of the cut for the bottom edge of each weatherboard is found by drawing horizontal lines from a and b to meet the scribed lines at a_1b_1. An oblique line from a_1 to b_1 represents the position of the cut for the bottom edge of a weatherboard. It would be too slow a procedure to set out this cut at every board and so a gauge (*Fig.* 356B) is made of a block of wood, with the head of a nail raised sufficiently for a mark to be made on the exact position corresponding to the line a_1b_1.

(3) The lower end of the scriber is marked with the compasses open to the vertical distance A_1 and the required line is scribed from the sill with the points of the compasses held vertically.

(4) When the scribers have been removed from the wall the edge cuts are usually sawn before the face cuts, care being taken to saw exactly to the marks. Both cuts are slightly undercut.

(5) To make a tight fit against the edge of the facing and also against the weatherboards, a scriber is secured by nailing on the skew through the side of the scriber, near its front edge, to the weatherboards. Nails are also inserted through the side of the scriber into the edge of the facing. A coat of priming paint should be given to the sawn edges before the scriber is fixed.

Scribers are commonly used throughout New Zealand, but in some parts the necessity for them is obviated by scribing parts of the window and door facings over the weatherboards.

Porch finishes

The finishing trim in a porch varies according to the particular kind of sheathing used on the walls of the porch. In some cases the general outside wall finish is continued into the porch, and at other times, the porch walls are sheathed with materials different from those on the outside of the building. Some of the materials used for sheathing porch walls are mineral fibre cement sheets, resin-bonded plywood, hardboard, weatherboards, vertical boards and battens, tongued, grooved, and V-jointed lining boards, brick, and stucco. The ceilings of porches are usually of plywood, hardboard, mineral fibre cement sheets, or other suitable material. Porches that have flush sheathing materials have a standard trim of D-type moulding over the joints, and a quarter-round or scotia moulding between the wall and ceiling surfaces. *Figs.* 357 and 358 show the typical finishing trim for porch walls sheathed with boards and battens. *Fig.* 359 shows how a post supporting the roof over a porch entrance is secured to the concrete floor.

Finishing trim of weatherboards against brick and concrete

The finishing trim of weatherboards against a brick or concrete wall is made as follows:

(1) Weatherboards butted against a metal flashing recessed in the concrete.

(2) Weatherboards butted to a piece of durable timber against the concrete, the joint being made waterproof when the concrete is plastered.

(3) Weatherboards continued over a concrete wall a sufficient distance to cover adequately the joint between

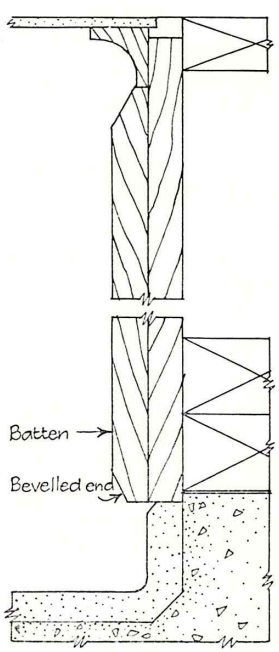


Fig. 357

Cross section of board and batten finish for porches

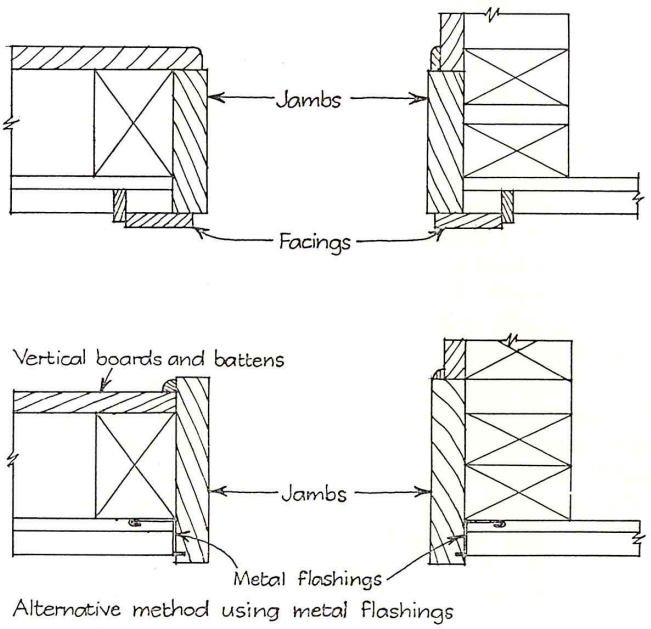


Fig. 358

Trimming at porch openings

the framing and the concrete, the ends of the boards being finished with a durable strip of timber.

(4) The ends of weatherboards finished within a quarter of an inch of the brickwork and the joint covered with a durable piece of timber scribed to the weatherboards and also to the brickwork.

Interior finish

The builder cannot commence interior finishing until all other trades have nearly completed their respective parts of the work.

Finishing work on a house usually conforms to the following sequence of operations. After the frame has been covered, the floor is laid, and then the partitions which have not already been secured are fastened in position. The electrician may now make a preliminary installation of conduits and wires, and the plumber carries his work a stage further.

While the work of other trades is being carried on within the building, the builder, if weather conditions permit, may complete the many jobs requiring attention on the outside of the building. When the electric wiring and water piping have been completed, and the wall and ceiling linings fixed, the interior finishing work may be commenced.

This work includes the fixing of interior door frames, the hanging of doors, and the finishing trim around rooms, windows, and door openings, etc., as well as the making or fitting of the many cupboards for the average house. When all the woodwork has been completed it is usual to fix the window and door fittings. Before painting is commenced these fittings should be temporarily removed to make it easier for the painter and also to avoid having the fittings marked with paint.

Hand dressing and finishing

In good-class work all interior joinery timbers are finished with a sanding machine in order to remove machine marks. If this has not been done the timber should be hand dressed, scraped, and glasspapered.

Hand dressing should be carried out as follows:

(1) The faces and edges of machine-dressed timbers are lightly dressed with a sharp, finely set smoothing plane.

(2) Plane marks and cross-grained patches must be eliminated by using a scraper. (Edges are not scraped.)

(3) Surfaces are now glasspapered with a medium grade of glasspaper (M2) and finished with fine (F2) or finer grade paper.

(4) The arrises are removed with glasspaper.

When using glasspaper it should be held under a "glasspaper cork" and the surfaces rubbed in the direction of the grain. To fit the hollows or rounds of mouldings it is necessary to use a shaped cork.

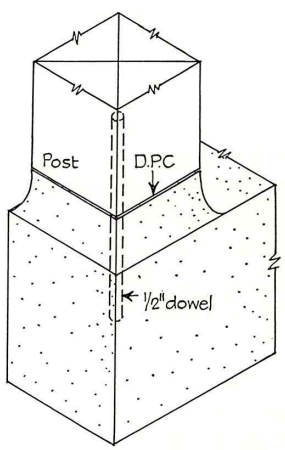


Fig. 359

Method of joining post to exposed concrete floor

Very little hand planing is done today because of the general use of sanding machines. Narrow mouldings, architraves, and skirtings that have not been machine sanded should be rubbed with glasspaper and cross-grained areas scraped and glasspapered to remove obvious machine marks.

Built-in fitments

Living room and kitchen cupboards, sideboards, and serveries are often built in between a kitchen and living room with access from both rooms, while built-in wardrobes, tallboys, and dressing tables are fixed in bedrooms.

Practically all fitments are made as units, or parts of units, in the joinery factory and consequently may be quickly fixed in place by the carpenter on the job. On

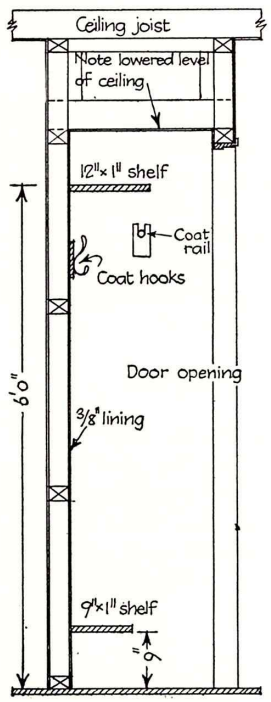


Fig. 360

Cross section through a wardrobe

most occasions cupboard doors are already hinged and only the locks and catches have to be fitted.

Wardrobes (*Fig.* 360)

Wardrobes usually have a depth of from 22 in. to 24 in. and a length ranging from 4 ft. 6in. in the case of a single wardrobe to 6 ft. or longer for double wardrobes.

Usually a wardrobe is lined with the same kind of wall-lining materials as used in the rest of the house. The ceiling may be the same height as other ceilings or it may be lowered.

The inside may be finished with a skirting and quarter-round mouldings in the corners. Every wardrobe should be ventilated by several holes bored in the ceiling of the wardrobe, and to exclude vermin and insects these holes are covered with fine rust-proof wire gauze.

In the majority of cases there is a shelf for shoes at about 9 in. from the floor and another shelf for hats fixed at a height of about 5 ft. 6 in. Under the top shelf there is usually a wooden or metal rail for coat hangers. In some cases there is a light batten for coat hooks placed across the back of the wardrobe. Door openings are finished with the usual trim of architraves around a door frame. The door is usually hinged but may be arranged to slide into the partition. This is frequently done in the case of double wardrobes where the space in the front of a wardrobe is likely to be limited.

Linen cupboard

Linen cupboards are lined with materials as used for wardrobes and, as a rule, have shelves made out of 1 in. boards at about 12 in. centres or in desired positions. The shelves are supported on ledges and are the full width and depth of the cupboard.

Coat cupboard

The internal finish for coat cupboards is much the same as for wardrobes, except that the rail for the coathangers and the lower shelf are omitted. Coat hooks are fixed at a convenient height. The door is often omitted in this type of cupboard and the opening is framed and lined with a set of plain jambs which are trimmed in the usual manner.

Bathroom cabinet

A bathroom cabinet may be of any size to suit the owner but a cabinet to suit average requirements is usually about 2 ft. high by 1 ft. 3 in. wide and 4 in. deep (*Fig.* 361). Either on the front or the back of the door, which may be of a solid-core type or framed, a bevelled plate-glass mirror is usually fixed with metal clips. Note that the width and depth of the cabinet is such that it can be fitted between studs spaced at 18 in. centres.

Sink bench (*Fig.* 362)

Sink benches are usually prefabricated units of timber framing supporting a bench top of wood, terrazzo, stainless steel, plastic, or other material. The height of a bench is usually about 3 ft. but really should be made to suit individual requirements.

Sink benches are mostly framed in 3 in. x $1\frac{1}{2}$ in. dressed timbers arranged for shelves, drawers, and other such facilities. A toe space is arranged under the whole length of the bench. Mouldings are used to cover the joints between walls and floor to which the unit is secured. Dwangs should have been previously placed in suitable positions for nailing purposes.

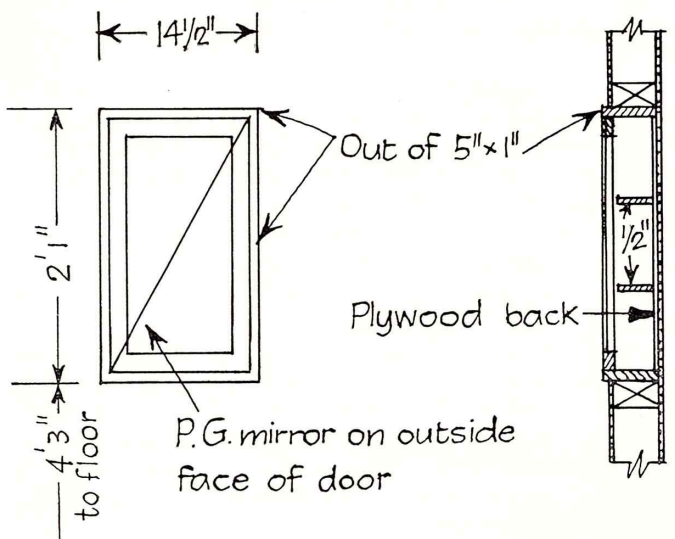


Fig. 361

Elevation and cross section of a recessed bathroom cabinet

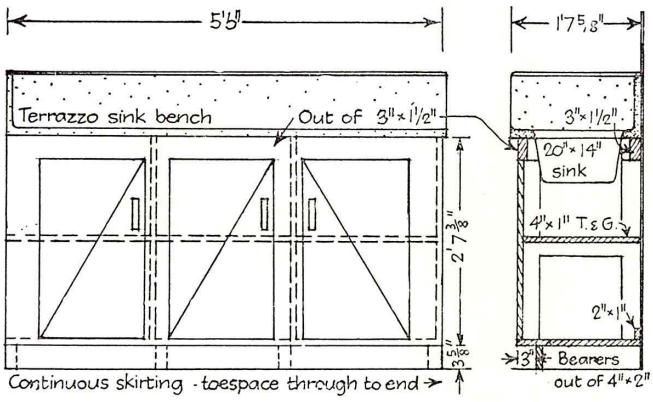


Fig. 362

Elevation and cross section of sink bench

Hot-water cupboard (*Fig.* 363)

A hot-water cupboard may be framed and lined as for wardrobes, or it may be prefabricated out of $1\frac{1}{2}$ in. thick material and sheathed with either plywood or hardboard. The space above the hot-water cylinder is frequently made into a drying cupboard with several shelves of spaced slats arranged on wall ledges.

Ventilating holes, covered with wire gauze, should be arranged in either the ceiling or the door of the cupboard. The doors are the same as for other cupboards.

Kitchen cupboards (dresser unit)

Typical kitchen cupboards (*Fig.* 364) are usually two separate units, the lower one having bins, cupboard space, and drawers, while the upper unit has shelves for storage.

The units are made out of 1 in. timber. Bench tops may be of wood, plastic, or other materials to match the finish on other benches in the room. A wooden bench top is usually $1\frac{1}{4}$ in. thick and the front edge is rounded slightly.

All drawers have $\frac{3}{16}$ in. plywood bottoms, but sides and front are of $\frac{1}{2}$ in. and $\frac{7}{8}$ in. timbers respectively. Each drawer back is housed into the sides and the bottom is grooved into the sides and front, and strengthened with glued blocks. The sides are either dovetailed or rebated into the drawer front. One drawer is usually subdivided into several parts for cutlery.

Shelves are of 1 in. dressed timber arranged at suitable spacings.

Doors for such units are frequently of the solid laminated core-board type, but a framed type with sheathings of either hardboard or plywood would be equally suitable. An advantage of core-board doors is that they do not warp to the same extent as other types of doors. In a kitchen where humidity varies greatly this is an important consideration.

Wall units are fixed by nailing through the horizontal battens placed across the back of the unit, under each shelf. In the angle between the wall and the unit a finish is made with a suitable moulding.

Food safe

A food safe (*Fig.* 365) is an ordinary cupboard that has shelves of slats spaced about $\frac{1}{2}$ in. apart to permit air to circulate from ventilation openings made in either the floor and ceiling of the safe or in an external wall. The ventilation openings should be covered with fine rust-proof wire gauze to exclude vermin and flies.

To prevent the entry of flies around the door a door stop should be fixed so that the door fits closely against it.

Access door in ceiling

A house with a pitched roof should always have a door in the ceiling of a room for access to the roof space. This door is usually in the laundry ceiling. The size of the opening should be about 24 in. x 16 in., and is trimmed in the usual manner, with architraves to match the surroundings. A core-board door is hinged to open back into the roof space.

Chimney breast (*Figs.* 366 and 367)

The walls enclosing a chimney and fireplace, known as a chimney breast, are of normal wall construction except

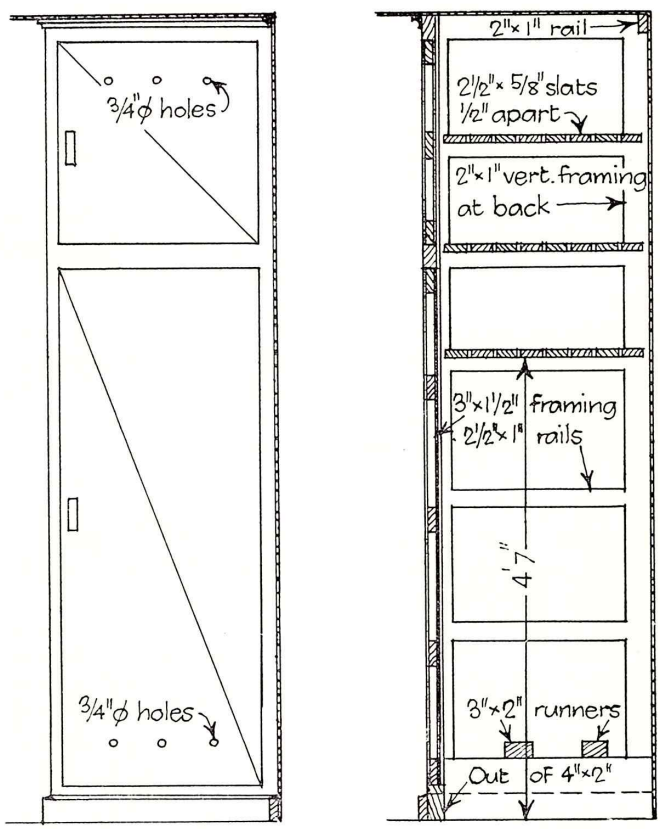


Fig. 363

Elevation and cross section of hot-water cupboard

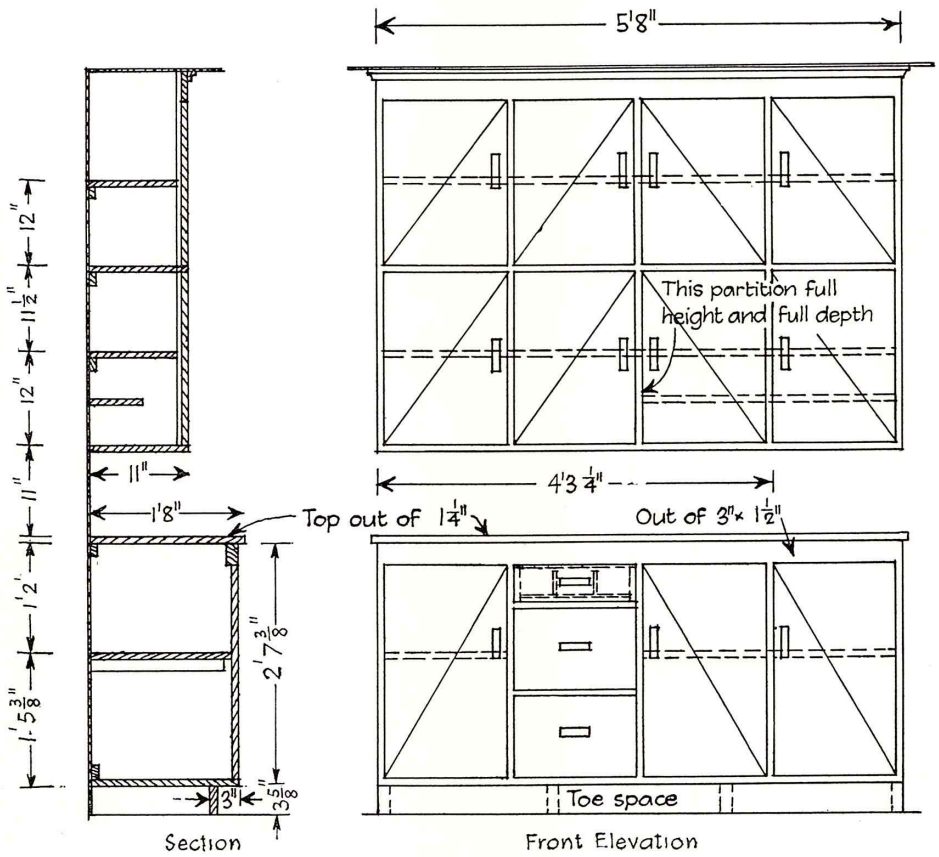


Fig. 364

Elevation and cross section of kitchen dresser unit

that the part of the wall above the fireplace is usually formed with the studs and dwangs turned on their flat instead of being the normal way. The purpose of this is to save space in the room. As a precaution against fire, all woodwork must be kept at least 1 in. away from the brick or concrete work. From the sides of the fireplace opening a distance of 8 in. is usually allowed. Dwangs must be located in positions for the fixing of the pre-cast fireplace surround (if one is being installed), the wooden surrounds, and the mantel shelf. *Fig.* 366 shows details of a mantel shelf and hearth kerb.

Framing for a bath

A bath is usually placed alongside a wall or in a recess or corner. It is boxed in on the side and sometimes at one or both ends with a timber framework covered with the particular wall-lining material used in the bathroom. Baths are sometimes supplied as a complete unit so that no boxing in is required.

A bath against a wall or in a recess is supported either on wall cleats or a cradle so that its top edges are level and the bottom of the bath has a fall to the outlet. The sides of the bath are framed with timber placed at the slope of the side of the bath or vertical, in which case a toe space is sometimes formed (*Fig.* 368). When the lining material has been fitted a finish is made with a skirting and quarter-round mouldings.

Along the top edge of a bath against the wall a skirting board or splashboard, as it is sometimes called, is fitted against the wall and hard down on the flange of the bath. This skirting board, which is usually about 6 in. wide and of heart-quality timber, is neatly fitted to the top edge of the bath flange, scribed at angles where necessary, and set in white lead to make a water-tight joint.

Architraves

The ornamental mouldings around window or door openings that cover the joint between the wall linings and window or door frames, are known as architraves. They have a variety of shapes but one commonly used is shown in *Fig.* 369. Architraves are mitred at the corners and fixed with their inner edges $\frac{1}{8}$ in. to $\frac{1}{4}$ in. back from the edges of the frames to form a margin. The most common architraves nowadays are narrow.

Setting out mitre cuts and fitting architraves

The architraves for a door frame, for example, are first

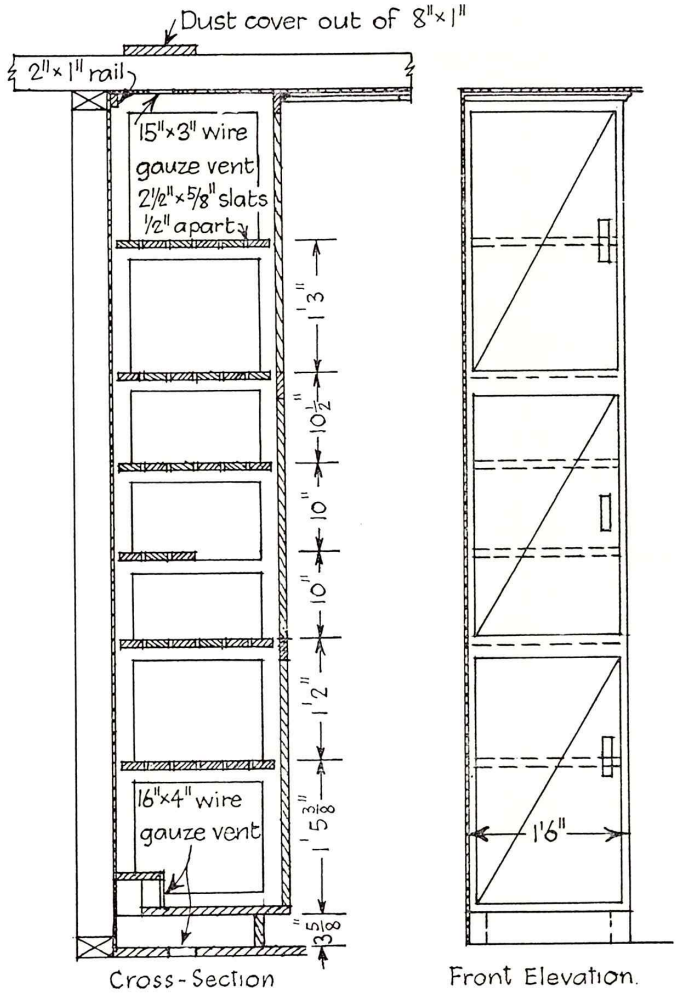


Fig. 365

Elevation and cross section of food safe

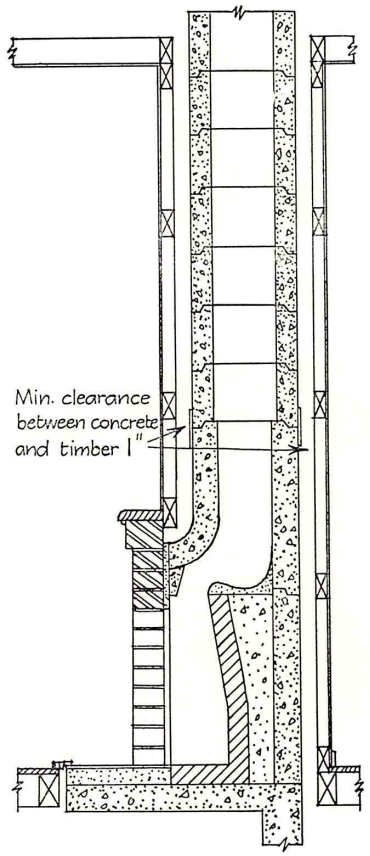


Fig. 366

Cross section through chimney and chimney breast (reinforcing steel not shown)

cut to approximate lengths, care being taken to allow sufficient length for the mitre cuts to be made on each piece. The operation of marking the mitre cuts is done by either of two methods as follows:

Method 1. Using a mitre square.

(1) Vertical architraves are sawn square on the lower ends to fit the floor.

(2) Each is tacked in position with a margin of about $\frac{1}{8}$ in. from the edge of the jambs.

(3) The short point of the mitre cut is marked $\frac{1}{8}$ in. up from the head of the frame so that the same margin is allowed at the head as on the sides of the frame.

(4) Using a mitre square or set, each mitre is marked and then sawn with a fine saw.

(5) The cut is usually planed with a finely set sharp smoothing plane or block plane.

(6) Each vertical architrave may now be either securely nailed or tacked in position. The horizontal head piece is held in place and either the long or the short points of the mitres on the vertical architraves are marked on the head piece. Mitres are marked, using a mitre square or set, and the cuts sawn and planed. The head piece is placed in position and if the frame is perfectly square the joint should require little if any fitting. Architraves are nailed to both the door frame and the wall framing.

Architraves are often fitted in a different order from that just described. The left vertical architrave, for instance, is first marked for length, mitred, and secured in the usual manner. The mitre cut in the left-hand end of a head piece is fitted to this mitre cut and the length of the head piece marked for length, mitred, and then secured. The other vertical architrave, which has already been fitted to the floor, is held in position and either point of the mitre marked from the head piece and the mitre marked and sawn in the usual manner.

Method 2

A mitre cut may be accurately determined by first tacking the vertical and horizontal architraves in position, with the usual margin allowance, and then marking the points of intersection on both horizontal and vertical pieces. Remove the architraves and mark the mitre lines through the points of intersection. After cutting, smooth the joint surfaces and then replace and tack the vertical architraves before placing the horizontal one. Test the joint, fit if necessary, and then securely nail.

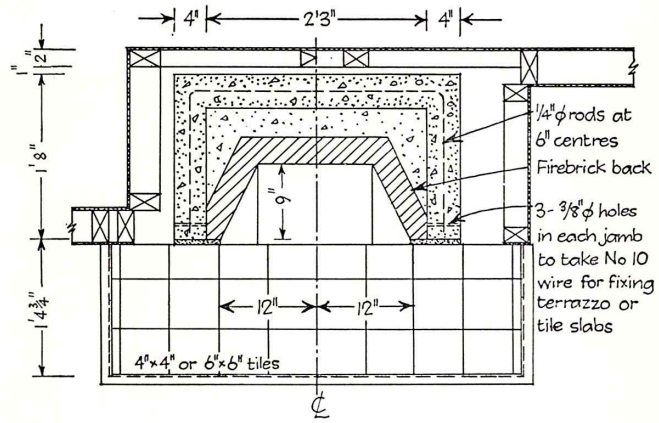


Fig. 367

Plan of fireplace and chimney breast

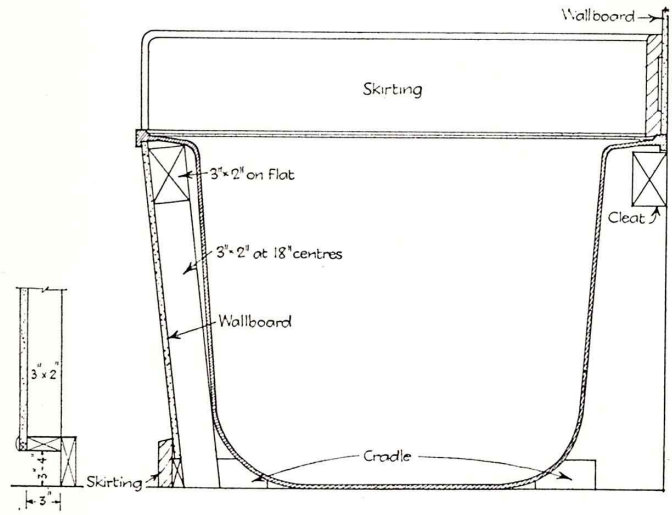


Fig. 368

Cross section through bath

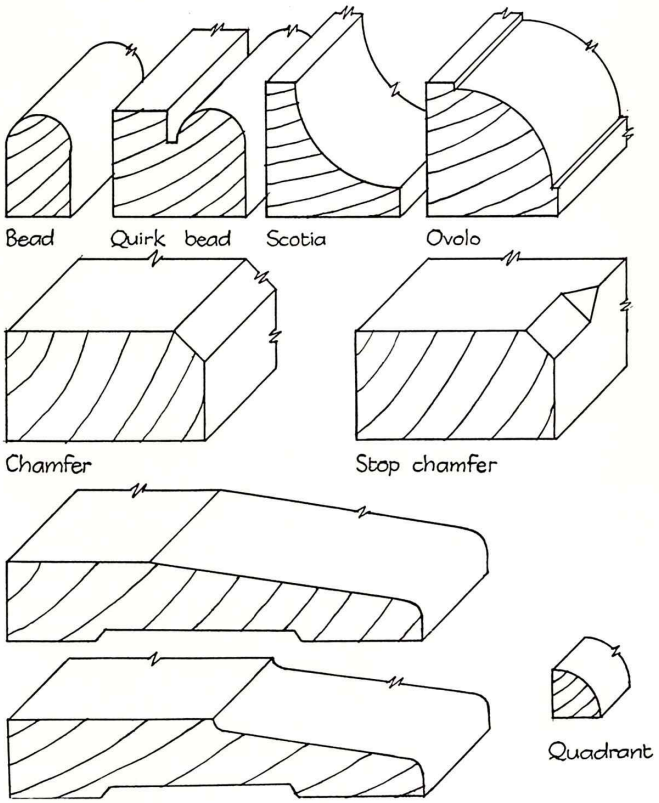


Fig. 369

Mouldings and architraves

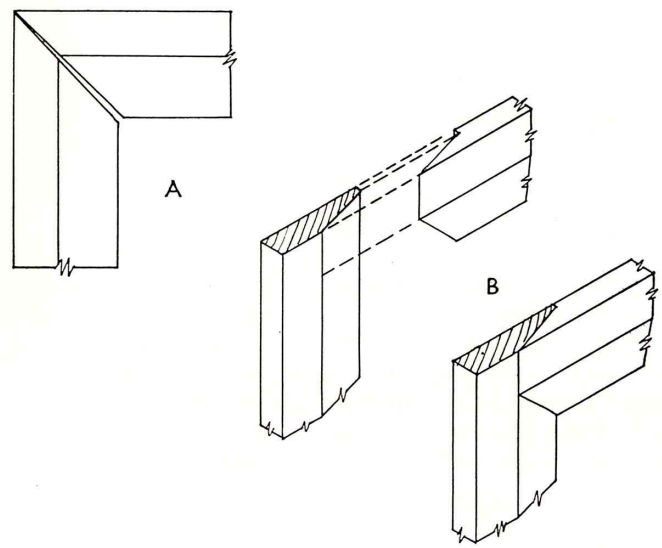


Fig. 370

Fitting of architraves

(A) *Mitred joint showing gap due to shrinkage*
(B) *Scribed joint*

Scribing of architraves

Sometimes specifications require that architraves be scribed as shown in *Fig.* 370. The making of such a joint possibly involves more fitting than a simple mitre, but it can minimise unsightly gaps due to shrinkage.

Window board

The cross section of a window board is shown in *Fig.* 371. Note the bevel on the edge of the board against the sash and the 3 in. x 2 in. packing under the board which provides a backing for the inside wall lining. *Fig.* 371 shows how the lower ends of the jambs and mullions are rebated for the window board. The lower ends of the vertical architraves on a window frame rest on the window board which must be made long enough to extend about $\frac{1}{4}$ in. past the outside of the architraves. This distance varies and must be equal to that from the front edge of the window board to the front of the architrave.

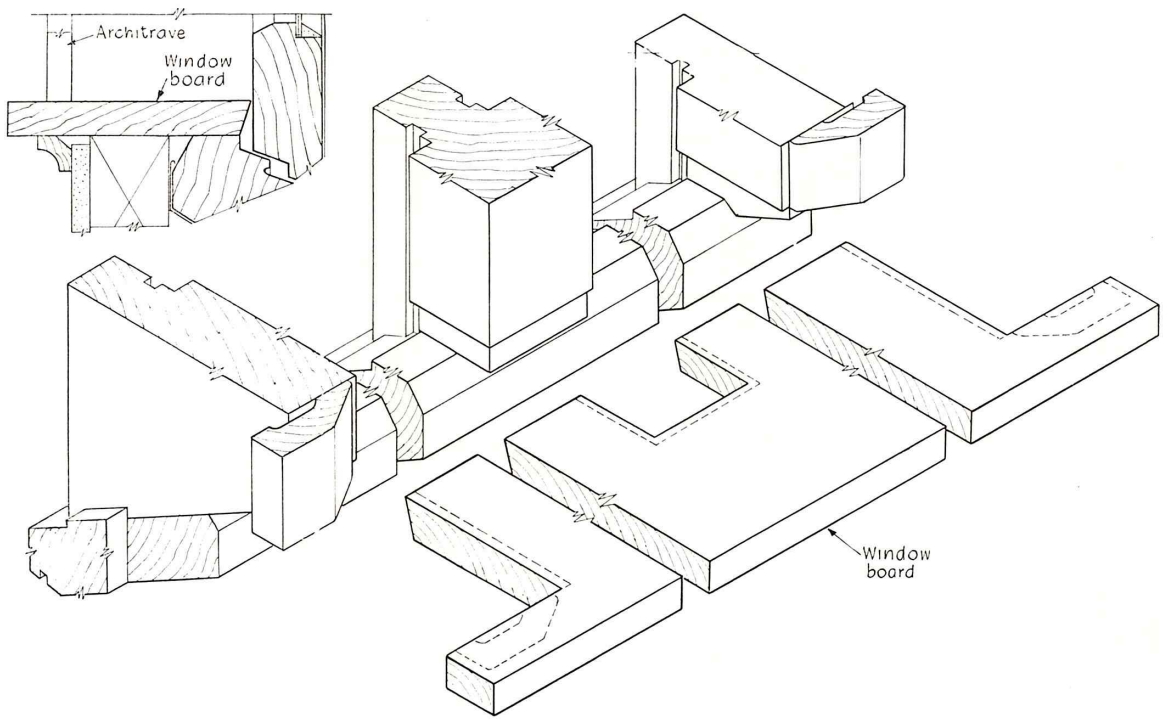


Fig. 371

Fitting window board

Pelmets

A pelmet is often placed over the top of a window to hide the blind and curtain fittings. In such circumstances, instead of mitring the architraves, the side pieces are simply butted up to a plain 3 in. x 1 in. head piece across the top of the window, and extended about 3 in. past the side architraves on either side to provide a support for the curtain fittings and pelmet.

Skirtings

Skirtings are butted against door architraves, scribed at internal corners, and mitred on external corners. Scribed joints generally should be arranged away from the most-used line of sight so that any shrinkage of the joint will be least apparent.

When scribing, the end of one piece must be sawn to the exact shape of the surface of another piece of skirting. This is done by either scribing the skirtings in place with wing compasses and then cutting to the mark (*Fig.* 372) or by making a mitre cut and then, with a coping saw, cutting to the outline of the mitre on the surface of the skirting (*Fig.* 373). The first method has the advantage of correcting any irregularities of either shape or position of the skirtings.

Preparation of skirtings

One wall in a room is measured for length, by means of extended rods, and then a piece of skirting with square ends is placed in position (*Fig.* 374, 1).

For the adjacent walls, pieces of skirting (*Fig.* 374, 2 and 3) are sawn with a scribed cut at one end and square at the other end, but slightly longer than the exact measurements so that the joints will be tight when the pieces are sprung into position. The process is repeated by scribing the ends of pieces (*Fig.* 374, 4 and 5) and placing them in position. They are marked for length to the back edge of the architrave about the door, and then each piece is placed into position and nailed.

It is customary to scribe the bottom edges of skirtings to the floor so that an open joint does not occur.

The skirting is first fitted around the walls of a room, placed parallel with the floor, and then a line is marked with wing compasses along the bottom edge of the skirting, just sufficiently far above the edge for easy cutting with a rip saw. This cut should be bevelled so that there is no doubt about the front edge fitting hard on the floor (*Fig.* 375). Sometimes a small quarter-round moulding is fixed in the corner of the skirting and the floor and this obviates scribing the skirting to the floor.

The splay joint is used for making a joint between two pieces of skirting on a straight wall.

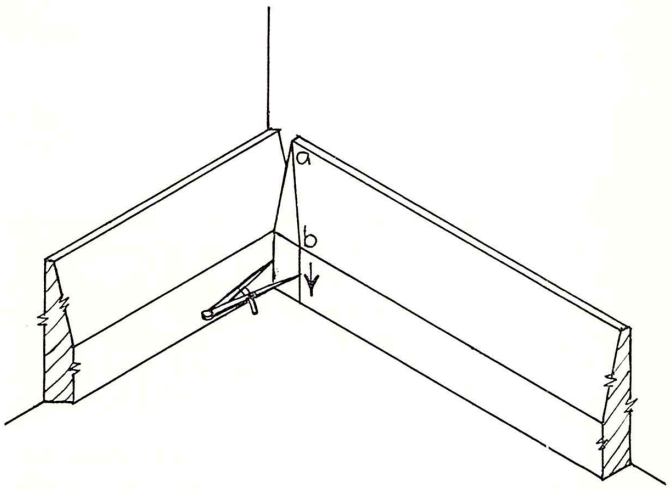


Fig. 372

Method of scribing skirtings

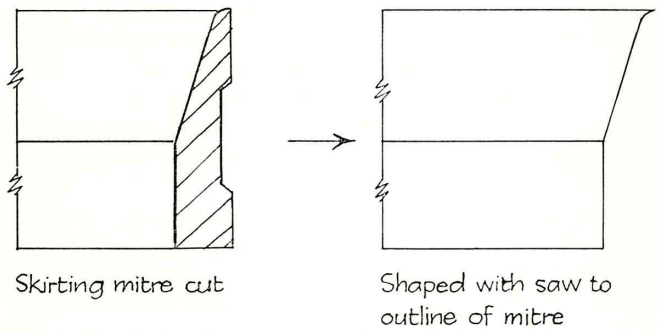


Fig. 373

Cutting skirting to the outline of a mitre cut

Cornices and mouldings

The methods of measuring the lengths and jointing of cornices and mouldings are identical with those used for skirtings. Joints in straight lengths are made with the usual splay cut. *Fig.* 376 shows the method used to scribe the end of a moulding.

Door and window locks and miscellaneous fittings

For the average house a list of fittings would include all door locks, door bells, socket bolts, cabin hooks, and door buffers or stops, and for windows, sash fasteners, stays, sash lifts, and fanlight openers; as well as such miscellaneous fittings as towel rails, toilet-paper holder, handrail brackets, and hat and coat hooks.

Door fittings

The front entrance door of a house usually has a night latch fitted as well as a mortise latch. The type of mortise latch on a bathroom or w.c. door should have a snibbing device or a socket bolt fitted as well as the latch. The latches on wardrobe doors only need the furniture placed on the outside of the door when the wardrobe is shallow but a deep one should have furniture on both sides of the door.

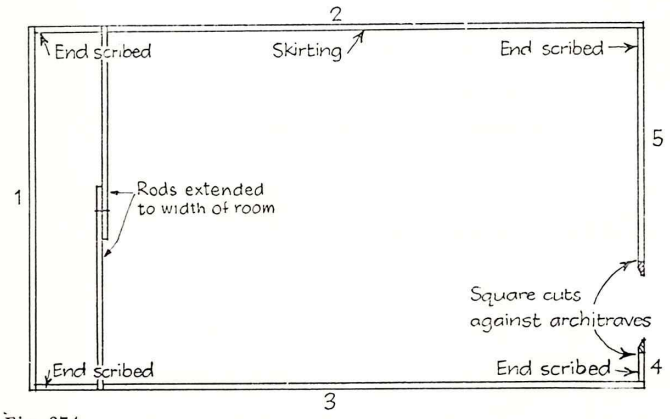


Fig. 374

Order of fitting skirting

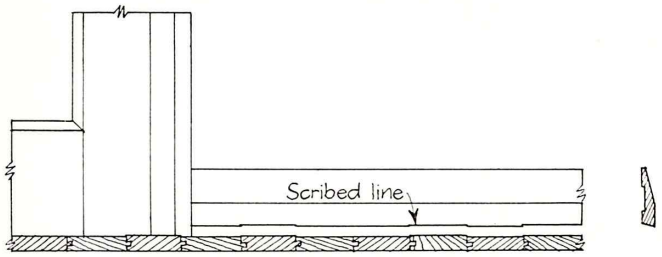


Fig. 375

Scribing skirting to floor

Rimlocks are usually fitted to laundry, basement, and tool-shed doors.

On account of the great variety of door and window fittings on the market it is impossible to give more than a bare outline of some of the fittings used and the usual method of fixing.

Cylinder rim night latch

A cylinder rim night latch is the type of lock generally fitted to a front entrance door. This lock consists of a cylinder, containing the locking mechanism which is located in a hole bored through the door stile. It is held in position by a back plate on the inside of the door. The latch case is fastened over the back plate and its mechanism connected to that of the cylinder by means of a connecting bar. The bolt on the lock engages a staple or keeper on the jamb of the door frame.

On most occasions in every lock set there is a leaflet of printed instructions issued by the manufacturer for the correct fitting of the lock. It is advisable to follow these instructions closely.

Interior door locks

One type of mortise lock used for interior doors, consists of a thin lock case inserted in a mortise in the edge of a door. On each side of the door, cover plates are placed over the holes bored for the key and the latch spindle. On the rebate of the door jamb a striking plate

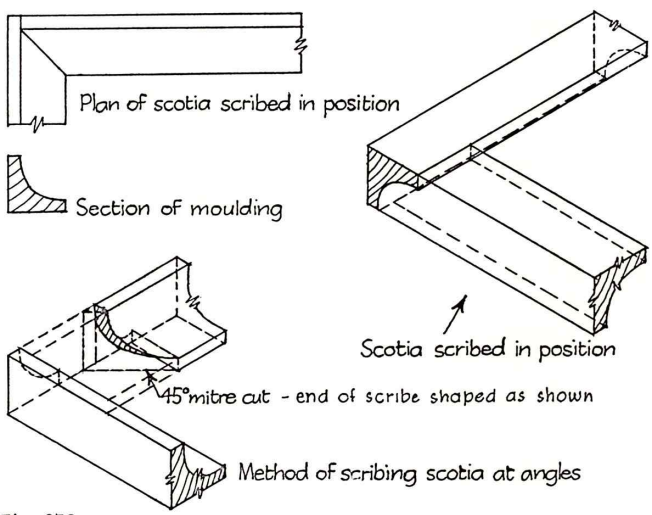

Plan of scotia scribed in position
Section of moulding
Scotia scribed in position
45° mitre cut - end of scribe shaped as shown
Method of scribing scotia at angles

Fig. 376

Scribing scotia at interior angles

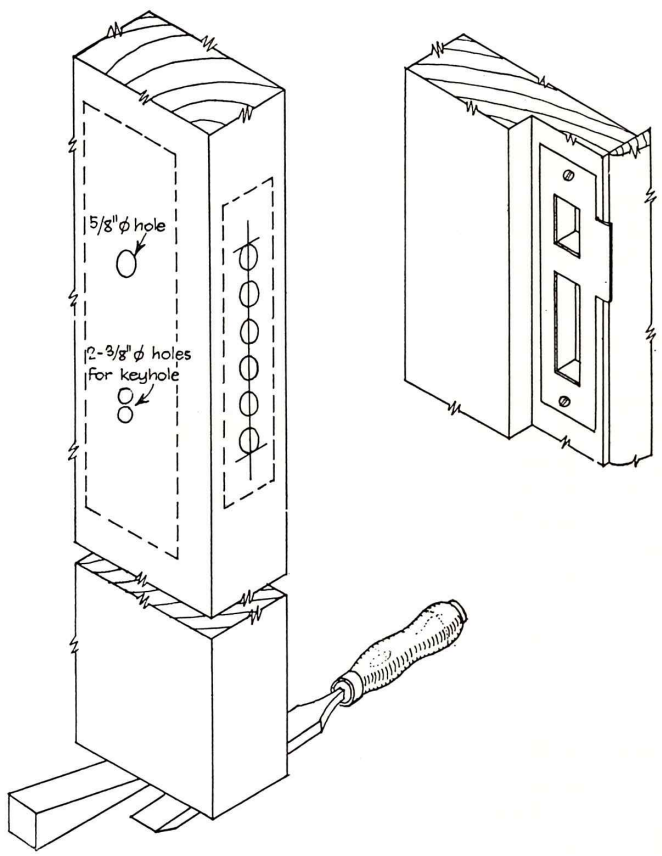


Fig. 377

Fitting mortise lock and striking plate

is fixed on which the bolt first strikes before the door is held in the shut position.

Fitting mortise locks

On some occasions the mortises for mortise locks are cut on a special mortising machine in the joinery factory and the carpenter has only to fit the lock in the mortise.

On the job a mortise is usually cut after the door has been hung. With the door open at any convenient angle, a wedge is driven under the closing stile and against the floor so that the door is held firmly while the mortise is cut and the lock is fitted (*Fig.* 377).

The position of the door handle is usually about 3 ft. from the floor and lines marking the centre and height of the lock case are carefully marked on the edge of the closing stile of the door as shown in *Fig.* 377. Using a bit slightly larger than the thickness of the lock casing, several holes are bored close to each other and to the centre line. The mortise is cut out with a mortise chisel and trimmed so that the lock case is a neat fit. The lock case is then inserted in to the mortise and the outlines of the end and face plates are marked and the housings for them are cut.

When the lock case is fitted into a mortise it often becomes fixed and cannot be withdrawn. To prevent this happening put a couple of screws into the holes on the front end plate of the case, with the threaded ends outwards, and then pull on them to remove the case. The lock is now placed on the rebate side of the stile immediately over the mortise (with the face plate firmly secured to the case) and flush with the edge of the door. With the point of a marking awl or a sharp pointed nail, the outlines of the holes for the spindle and key are marked through the particular openings in the lock case on both sides of the stile. The centres of each are marked and boring is done from both sides of the door. The keyhole is shaped with a keyhole saw. The lock is placed in the mortise, the front end plate being screwed to the stile before the face plate is secured. If the housing for this plate has been properly done the face plate should be flush with the edge of the door. The spindle with a knob attached at one end is put through the door after the cover or escutcheon plates have been secured, and the other knob or handle is then fixed by turning the machine screw which holds it to the spindle.

The mortises for the lock and latch bolts are now marked on the jamb. The exact positions are found by measurement. The mortises for the bolts are cut first and then the striking plate, also called a keeper, is held on the jamb. After light lines have been marked around its edges the sinking is made and the plate screwed flush with the surface of the jamb.

It is worth mentioning that the bolts of mortise locks are reversible and so may be used for either left- or right-handed doors.

Rim lock

A rim lock is screwed to the inside surface of a door stile, the spring catch and bolt engaging the staple box fastened to the jamb of the door frame. This type of lock is also reversible and may be used on either the left-hand or the right-hand door stiles. In a cheap form it is used on doors to out-buildings, while for rear doors of residential buildings a superior grade of lock is available.

Cupboard locks and catches

Fasteners for cupboard doors are usually of three types, the interior surface lock operated by a key, the exterior surface catch operated by a knob turn or pull, and spring catches for interior fitting. With interior surface locks and interior spring catches, door knobs or handles of some type must be provided.

So numerous are the various types of cupboard catches that the best advice is to follow the makers' instructions in the leaflet enclosed with the fitting.

Drawer pulls

On drawers one or two pulls are provided depending on the width of the drawer, two pulls being required on the wider drawers. Draw pulls or handles are fixed a little above the centre line.

Window fittings

Double hung sashes

The fittings for double-hung sashes include patent sash balances, sash lifts, and sash fasteners. In the past sash weights suspended on cords have been used to balance double hung sashes but nowadays spring balances are used. A common type of spiral balance will now be described.

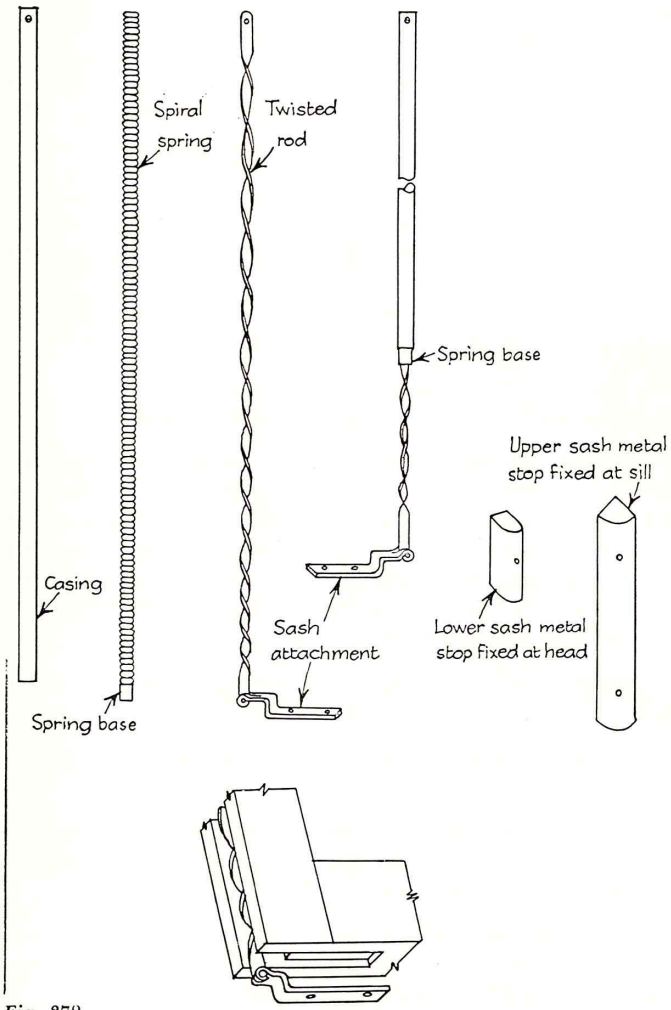


Fig. 378

Parts of spiral-spring balance

Spiral balances

A spiral balance consists of a coiled spring, and a twisted rod enclosed and free to revolve in a cylindrical tube which is screwed to the pulley stile while a sash attachment is fixed to the sash.

Fig. 378 shows a spiral balance taken apart, one complete, and the two metal stops supplied with the fitting.

In the assembled balance the twisted rod is inside the spiral spring and the base of the spring is grooved to fit the spiral of the twisted rod. The spring will therefore be compressed if the twisted rod is pulled down without revolving as this action will cause the spring base to revolve. When an upper sash is lowered the twisted rod cannot revolve as the sash attachment is housed into the bottom rail and therefore the spring is compressed. This compressed spring acting on the twisted rod tends to raise the sash so that by adjustment the weight of the sash can be balanced by the tension of the spring.

Note in *Fig.* 378 how the pitch of the turns of the twisted rod decreases as it approaches the sash attachment. This variation in pitch compensates for the differences in the tension of the spring when it is wound up tightly (sash lowered) and when it is slack (sash raised).

When the spring is tightly wound, it exerts a great force, but, since it is now applied to the rod where the pitch of the run is steep, the lifting force on the sash remains about the same as when the spring is slack and is operating on a flat pitch.

In installing the balances, the tension on the spring is adjusted to allow for the weight of the sash; the spring and the varying pitch on the twisted rod then balance the sash at any point throughout its run and make it easy to operate in any position.

Fitting spiral balances

Spiral balances are supplied in various sizes according

to the size and weight of the sash. For standard sashes the overall height between the sill and the head of the frame fixes the size of the balance required.

Two balances are required for each sash – the balances for the upper sash being shorter than those for the lower sash.

To fit the balances, proceed as follows:

(1) Both ends of the bottom rail of the lower sash and the meeting rail of the upper sash are housed for the sash attachment. This is shown in *Fig.* 378.
The grooves in the stiles of the sash to take the spiral balances have already been taken out by the joiner.

(2) Fit the upper sash in the frame and replace the parting beads. Try the sash for ease of movement.

(3) Lower the upper sash to rest on the sill and then insert a short balance (sash attachment down) into the groove cut in the sash stile. Raise the tube until it is hard against the head of the frame. Make sure the seam is against the jamb and then screw in place taking care that the tube is positioned so that the sash can run up and down without fouling it.

(4) Repeat with the other short balance on the other side of the frame.

(5) Raise the sash to the top of its run and prop up in place.

(6) Tap down the metal stops, supplied with the balances, in the bottom corners of the sill hard against the facing and the sash groove, and screw in position.

(7) The twisted rod will now most likely be unwound to its fullest extent. If so, screw to the left until the sash attachment is up to the meeting rail.

(8) Hold the sash attachment in the hand, so that it will not revolve, and pull it down aproximately 6 in.; then allow it to rise without turning.
It should be pulled up by the spring acting on the twisted rod. If this does not happen, give the rod a few more turns to the left.

(9) Pull the sash attachment down again and give three more extra left-hand turns and then fix it temporarily into the housing in the meeting rail.

(10) Attach the other balance to the other side of the sash in the same way. The tension of the springs acting on the twisted rods should now balance the weight of the sash.

(11) Run the sash up and down to test for balance. If it drops when closed, add some more left turns to *each* balance; if it is harder to pull down than to push up, take off some turns from *each* balance.

(12) When the sash is properly balanced, screw home the sash attachments.

(13) Fit the lower sash in the frame and fix the staff beads.

(14) Insert the long balances in the lower sash, as in (3) above.

(15) Fit the metal stops on either side of the frame hard up to the head and between the balance tube and the parting bead.

(16) Raise the sash to the fully opened position and then carry out the same procedure as outlined in steps (7) to (11) above.

Note: When upper sashes have joggles, bend the sash attachment around them and house in the usual way.

Sash lifts and fasteners for double-hung windows (Fig. 317)

Double-hung sashes have sash lifts which provide handholds for raising or lowering the sash. To raise the lower sash, sash lifts, one type of which is illustrated, are screwed to the lower rail of the bottom sash.

The type of sash fastener shown provides a secure lock to the sashes when closed and should be fitted at the middle of the meeting rails.

Fittings for casement sashes

A fitting must be provided for fastening a sash when it is shut and also one for holding it open at any desired angle. A casement stay is used to hold a sash open and a casement fastener to retain it tightly shut, but there are casement fittings available which serve the double purpose of both staying and fastening.

Casement fastener

A sash fastener is required to lock the sash in its closed position. One type of fastener is located towards the centre of the closing stile of the sash.

Combined casement stays and fastener

A simple type of combined stay and fastener consists of a bar, holed at about 2 in. centres, which is attached by a pivot to a small plate screwed to the inside face of the sash stile. Screwed to the jamb is a combined peg and keeper.

Friction type casement stay

This type of casement stay consists of a rod sliding in a tube, one end being fastened to the rail of the sash by a pivot attachment and the other to the sill board by the same means. Tightening or loosening a thumb screw fixes the sash in any desired position within the length of the stay. With this type of stay a separate sash fastener must be used.

Quadrant stay

A quadrant stay has a slotted metal bar, in the shape of a quarter of a circle, attached at one end by a pivoted

joint to a plate usually fixed to the stile of the sash or fanlight. The sash may be held in an open or shut position by a thumb-screw turning in a screw plate on the jamb of the frame.

Hinges

Hinges are mostly of steel and are available with the following finishes: bright steel, galvanised, or antique copper finish on steel.

Butt hinges are always used to hang windows and doors, the antique copper or bright steel finished hinge being used on interior work, while the galvanised finished hinge is used where hinges are exposed to the weather. A butt hinge should never be used as a surface hinge or screwed into the end grain of door tenons, where the screws will not hold.

Most hinges nowadays have loose pins which allow the flaps of the hinges to be separated when the pin is removed. This proves of great advantage when hanging a sash or a door because of the ease with which the door or sash may be removed by removing the pins from the hinges.

The following is a table of the common sizes of hinges and screws for sashes and doors.

Hinges and screws for doors

Type of door	*Hinges*	*Screws*
Internal	1½ pairs 3½ in. x 2¼ in., antique copper on steel butts, loose pins	1 in. x 9 gauge wood screws
External	1½ pairs 4 in. x 2¾ in., galvanised butts, loose pins	1¼ in. x 9 galvanised screws
Basement doors less than 4 ft.	1 pair 8 in. galvanised T hinges	1½ in. x 9 galvanised screws
Basement doors exceeding 4 ft.	1½ pairs 8 in. galvanised T hinges	1½ in. x 9 galvanised screws
Kitchen cupboard	1 pair 2½ in. galvanised butts	¾ in. x 7 galvanised screws

Hinges and screws for sashes

Type of sash	*Hinges*	*Screws*
Side-hung sashes less than 4 ft. 5 in. in height and fanlights	1 pair 3 in. x 2 in. galvanised butts with fixed brass pins	1¼ in. x 7 galvanised screws
Side-hung sashes exceeding 4 ft. 5 in. in height	1½ pairs 3 in. x 2 in. galvanised butts with fixed brass pins	1¼ in. x 7 galvanised screws

Special window hardware, which replaces hinges, should have a galvanised or chrome finish and be secured with appropriate screws.

Gates are hung on galvanised T hinges with 1½ in. x 9 gauge galvanised screws, the number of hinges used depending upon the size of the gate.

T Hinges and strap hinges

Surface hinges of this type are made of steel with bright steel, galvanised or black japanned finishes. They are obtainable in heavy and light grades and used for garage doors and gates. Where two doors are hung, one to the other, strap hinges are used.

Socket bolts

These bolts consist of a plate fitted with a sliding bolt and a socket plate for the bolt to engage. They are used as an interior door bolt to increase the security of a door lock and in double door construction to fasten one door so that the second door may lock into it. Socket bolts are available in various grades and finishes. Small bolts for joinery and cabinet purposes are obtainable either in cast bronze or in antique copper on steel. For use in outbuildings socket bolts are either black japanned or galvanised pressed steel. The size of a socket bolt is expressed as the length of the bolt plate and for general purposes the usual lengths are 4 in., 6 in., and 8 in.

Questions on Chapter 12

(1) Sketch the various methods of finishing a roof at the gable when the roof is covered with:
(a) Corrugated iron.
(b) Tiles.
(c) Mineral fibre cement sheets.

(2) Sketch a boxed eave and also name the various parts.

(3) Describe how you would fit fascia boards and also line the soffit with mineral fibre cement boards. Assume a flat roof and allow for ventilation.

(4) Explain, with sketches, how you would fit a scriber alongside a facing in bevel-back weatherboard construction.

(5) Various means are adopted in joinery to prevent the flow of water between surfaces that are close together. Name and sketch the various devices that are commonly used to overcome this difficulty.

(6) (a) What are the eaves of a house and what purpose do they serve?
(b) State where the "verge" is located.

(7) The walls of a front porch of a house are to be lined with vertical boards and battens. Briefly describe these boards and battens and the method of fixing them.

(8) A building is to be covered with a tile roof having a 32° pitch. Draw the section through the roof showing boxed eaves.

(9) Explain how you would cut and fit 4 in. bevelled skirting in a bedroom of rectangular shape with the door opening in the centre of one long wall.

(10) (a) What is a pelmet and how is it arranged?
(b) How would you fit architraves around a door?

(11) Describe the method of fitting a mortise lock on a door and frame.

(12) How are patent sash balances fitted to double-hung sashes?

(13) Briefly describe how a smooth surface is achieved on finishing timbers and also state how such a finish is obtained without the use of machines.

(14) Draw a plan and vertical section through wardrobes built between bedrooms.

(15) Draw a vertical cross-section and a front elevation of a typical hot-water cupboard. The cross-section should be parallel with the side wall of the cupboard.

(16) Sketch front elevation and section of a typical kitchen cupboard showing cupboards and drawers below bench level. Above this show a cupboard for general storage purposes.

(17) What advantages have built-in fitments and where are they located in a house?

Calculations

(1) A cutting with sides which slope at the same inclination is 23 ft. wide at the top, 17 ft. wide at the base, and 10 ft. high. Find the area of its cross section.

(2) A builder buys a planing machine for £850 and he estimates that at the end of each year its value has depreciated by 15 per cent of its value at the beginning of that year. At the end of which year will the value of the machine have fallen below £600?

(3) Find the area of the curved surface of each of the following solids:
(a) Cone with a radius of $10\frac{3}{4}$ in. and a slant height of 18 in.
(b) Sphere with a diameter of 8 in.

(4) A screw moves through a distance of $\frac{5}{32}$ in. for each complete turn. How many turns are required to move it $2\frac{1}{8}$ in.?

(5) A carpenter is paid at the rate of 7s. 6d. an hour for a forty-hour week. If overtime is worked, time-and-a-half must be paid. Calculate the wages of six men on a country contract working sixty hours per week.

Chapter 13

ATTENDANCE ON OTHER TRADES

The builder is responsible for the trimming work required by the sub-contractors, who must rely on the builder to have this work done at the proper time.

The carpenter should therefore oblige with his services when they are required by the various other tradesmen on the job.

In this chapter we shall discuss the work of the various sub-contractors on the average house, when they may be expected on the job, and how the carpenter may assist in the work.

Plumber

Briefly stated, the work of the plumber is to bring water on to the job, make it available in various parts of the building, and finally provide means of getting rid of the waste water. In addition he has to provide various flashings to keep unwanted water out of the building, i.e., he has to make the building weatherproof.

From the water connection installed by the local authority at the boundary, the plumber arranges a temporary water supply to the concrete mixer. In some circumstances it is necessary to have a drain under a house and when a permit has been granted for such, it is often more convenient to have the drain laid before the house is erected.

The next visit of the plumber will be after the frame has been erected when he installs the hot- and cold-water supply pipes, and if the floor has been laid, the waste pipes. Where vertical pipes are necessary to bring the water above fittings such as baths and sinks, holes are bored in the bottom plate. These holes should allow a loose fit for the pipes passing through them. Where no clearance is allowed for hot-water supply pipes, expansion and contraction will cause noisy creakings. On the other hand excessive clearances around pipes unduly weaken the timber and provide access for mice and other vermin into the walls of the house.

Sometimes pipes are run across the studs, e.g., the water supply to the tubs. In these cases care must be taken to make sure that the studs are not cut too deeply by having unnecessarily large checks taken out of them. In general, the checking of studs and plates for the passage of pipes should not be greater than $\frac{5}{8}$ in. for 3 in. wide framing or 1 in. for 4 in. framing. Holes bored for pipes should be made at the centre of the stud or plate and be of not more than 1 in. diameter for 3 in. framing and $1\frac{1}{2}$ in. diameter for 4 in. wide framing.

Attendance on plumber

Dwangs are necessary for securing the top ends of vertical pipes into which taps are screwed. Dwangs are also suitably placed to support the basin, w.c. cistern, and other such fittings.

When a pressure-reducing valve is not fitted on the cold-water supply to the hot-water system, a tank stand must be built on the ceiling joists for the supply tank.

It is good practice to leave one of the ceiling joists loose until the plumber has manoeuvred the water tank into the ceiling space.

When an access door has not been provided in the foundation walls, it would be helpful to have the trapdoor, or at least an opening, made in the floor before the plumber has to secure any waste pipes and traps under the floor.

Although in most cases the metal flashings and sill trays are supplied by the plumber, the carpenter often saves much delay by fixing them. Where the chimney and the roof intersect, the carpenter must fix trimmers between the rafters, and at times secure packings about the chimney for the flashings, which are completed by the plumber.

The plumber returns to the job during the finishing stages to fix and connect up the various fittings such as the sink, basin, bath, and w.c. to the water supply and drainage system.

When the wall linings are being fixed, if it is noticed that certain dwangs for the securing of plumbing fittings have been omitted, time is saved if the carpenter secures such timbers.

Telephone

If a telephone is being installed, the Post and Telegraph Department should be notified before any wall or ceiling linings are fixed. The telephone cables can then be installed easily and when the house is finished all the cables are hidden. When a telephone is fixed on a wall or recessed into a partition the carpenter may be required to fix dwangs and later provide a finish around the fitment.

Plasterer

The plasterer arrives on the job at any time after the floor has been laid, but usually when the interior finishing is nearing completion.

All the finishing trim on the outside of the building should have been completed so that the plasterer is not delayed in his work of plastering the concrete foundations, the concrete porch floors and upstands, laundry slab, and chimney, and also applying, where it is required, the stucco finish on the outside walls. The plasterer also fixes the ventilators and sometimes

the hearth and fireplace surround, although this latter job is often done by specialist contractors.

Fibrous plasterer

All the interior framework with the necessary dwangs in position must be completed before calling in the fibrous plasterer.

The fibrous plasterer works through the house room by room erecting the ceiling and wall sheets and after these are in position the carpenter carries on and finishes off each room by fixing architraves, skirtings, etc.

The skirtings and mouldings in a room are usually fitted after the wall sheets have been fixed but before the joints have been stopped. During this process water and plaster of paris are splashed on the surrounding woodwork and floor and no harm is caused when it is to be painted. If, however, woodwork which will have a varnished finish is so splashed, the stains left by either the water or the plaster of Paris cannot be easily removed and so the woodwork must be protected before the stopping work is commenced. Floors should be protected for the same reason, and also because ingrained plaster of paris causes excessive wear on the abrasives used on the sanding machines should the floors be sanded.

Roofing contractor

The carpenter must make sure that the roof frame is complete before he asks the roofing contractor to come on the job. All of the following work should be completed: (1) fascia and soffit; (2) chimneys; (3) terminal and back vents; (4) overflow from water-supply tank; (5) exhaust from hot-water cylinder; (6) valley and chimney flashings.

Drainlayer

In districts where the local authority has installed a sewerage system the drainlayer lays the house and stormwater drains and connects them to the main system. In some districts the stormwater and foul drainage discharge into the one sewer, but more frequently the stormwater is discharged into the street channels and the foul drainage into a sewer.

In districts where there is no sewerage system the drainlayer connects the house drainage to septic tanks and the stormwater to soakpits.

The drainlayer can complete his work at any time after the frame is up, but it is good practice to have him arrive on the job when the weatherboarding has been completed. If this is done his trenches do not interfere with the carpenter's scaffolding and he has a clear run for his excavations.

Attendance on drainlayer

The only time that the carpenter has to provide for the drainlayer is when he is required to trim around the floor joists where the upstand from the drain connects with the w.c.

Electrician

When the building has been covered in, the electrician should be advised so that he may conveniently run his conduits or cables along the ceiling joists and down the studs to the various outlets before the wall linings are fixed. Aerial and earth wires for radios are also installed at this stage.

Besides installing all the wires for the lighting and heating circuits throughout the building, he runs the electrical wires for the main supply from the meter to the point of entry outside the building. The electric power supply lines will be connected only after the work of the electrician has been tested and passed by the electric power supply authority.

Attendance on electrician

The carpenter cuts in dwangs where required at the various lighting and heating outlets and switches.

When tough plastic- or rubber-sheathed cables are used in place of conduits the carpenter sometimes helps the electrician by bridging the ceiling joists where required with 3 in. x 1 in. boards on their flat. The electrician then tacks his cables to the edges of these boards.

The carpenter must also trim for the switchboard.

Where the timbers supporting the service-line insulators at the entry point have to be strengthened the carpenter again helps out by placing dwangs at the back of the barge board or weatherboards, as the case may be.

Painter

The first job done by the painter is the priming of the weatherboards which are stacked on two stools, where the edges are first painted, and then the face and lap of each board. When the weatherboarding has been fixed and the joinery primed and in place, the painter later completes the painting of the outside of the house. His work inside includes painting, enamelling, varnishing, and the papering of walls and ceilings as required.

Attendance on painter

The painter usually brings his own scaffolding, but on steeply sloping sites he should be able to make use of the carpenter's scaffold.

Before the painter commences interior finishing work it is advisable for the carpenter to remove all hardware. When the painting has been completed the fittings are replaced.

Bricklayer

Except in houses of brick or concrete-veneer the work of the bricklayer is mostly confined to the erection of a brick chimney and fireplace. Many residences have chimneys of precast concrete and these may be erected either by the bricklayer, the carpenter, or the contractor who specialises in such work. A chimney is built after the framework has been completed but before the roof covering has been laid.

The bricklayer usually supplies his own scaffolding and all the carpenter has to ensure is that the trim in the ceiling joists and rafters is ready for the chimney stack to pass through.

On a brick or concrete-veneer job the bricklayer commences work after the timber framework of the house has been completed and the window and door frames are in place. When the brickwork is completed the carpenter may have to provide a finish with a moulding between the brickwork and the soffit lining.

Questions on Chapter 13

(1) At what stages in the building of a house should the builder arrange for the following tradesmen to carry out preliminary work on the job?

(a) Plumber.

(b) Electrician.

(c) Painter.

(2) Why is it necessary for the carpenter to know the position in the framing of the water-supply pipes?

(3) In the building programme when does the roofing contractor start work? Give details of the other sub-contractors' work which must be completed at this stage.

(4) What works are completed when the roof of a house has been secured and the building made weather-proof?

(5) Describe the precautions taken to prevent window and door hardware being spotted with paint.

Calculations

(1) The panelling between the string and the handrail in a straight flight of stairs is in the shape of a parallelogram. If the handrail is 17 ft. 6 in. long and the shortest distance between the handrail and string is 2 ft. 6 in., what will be the cost of the plywood at 1s. 3d. a square foot?

(2) The length of shelving required to accommodate 1,278 books in a library is 160 ft. How much more shelving would be required if the books were increased to 2,000? (Answer to the nearest foot.)

(3) Four houses with frontages 25 ft., 30 ft., 32 ft., 35 ft. share the cost of street levelling amounting to £285 10s. What should each householder pay if he pays in proportion to his frontage?

(4) A circular saw is 15·4 in. in diameter. What is the speed of the edge of the saw in feet per minute if the machine is driven at 1,000 r.p.m.?

(5) Find the area of the glass in six windows, each window containing three rectangular panes 1 ft. 10 in. by 1 ft. $1\frac{1}{2}$ in.

Chapter 14

SCAFFOLDING

The temporary framework of timber that is constructed about a building during its erection includes falsework or formwork for concrete, and timbering for shoring, excavations, and scaffolding.

In this chapter only the temporary carpentry work of scaffolding and the timbering of shallow excavations will be discussed. Such works must be carried out according to the provisions of the Construction Act 1959 and the Construction Regulations 1961. As amendments are often made to regulations from time to time, the student should obtain a current copy of the regulations in force and use it as a guide.

Requirements of Act and Regulations

Twenty-four hours' notice must be given to the inspector of scaffolding before the following works are commenced:

(1) The erection of any scaffolding or building that entails the risk to any person of a fall of 15 ft. or more.

(2) The erection of any crane.

(3) The making of any excavation 6 ft. or more in depth.

The general provisions of the Construction Regulations regard the employer or the person employed by him as a Safety Supervisor as being responsible for carrying out, to the satisfaction of the Safety Inspector, any such works as may be necessary for the protection of workmen and other persons about a building.

Scaffolding

Scaffolding is any structure, framework or swinging stage used for the support and protection of workmen engaged in building. Except for a swinging stage, scaffolding usually comprises horizontal, vertical, and diagonal members of either timber or metal upon which scaffolding planks are laid. As a man cannot work satisfactorily at a height greater than 5 ft. above where he stands, a scaffolding must be erected as the building increases in height.

Types of Scaffolding

Although the provisions of the Construction Regulations cover the erection and use of a wide range of scaffolding and gear for carpenters and other tradesmen, we shall deal with only those matters that particularly concern a carpenter on scaffolding and timbering for excavation works in and about residential buildings of timber and brick construction.

The type of scaffolding used on a particular job will largely depend upon the kind of building being constructed. In modern practice, steel scaffolding is extensively used in and about buildings. On small jobs the carpenter is often required to erect such scaffolding but on buildings of considerable height scaffold hands or riggers do this work.

Fundamental requirements of scaffolding

The fundamental requirements of scaffolding are strength, firmness, and safety. Sound practical methods must be used when erecting scaffolding and the principle of "safety first" adopted and rigidly adhered to.

Timber for scaffolding

The timber for scaffolding should be of first-class quality, strong, well seasoned, straight grained, and free from large knots and other defects. Oregon is the most suitable timber, being both strong and comparatively light in weight, but other timbers may be used.

Scaffolding members (*Fig.* 379)

The names and description of the various scaffolding members are given below:

Standards or poles

Standards are the vertical members of scaffolding that transmit the loads to the base. They should rest on a solid foundation.

Ledgers

Ledgers are the horizontal members which tie and secure the standards. In a bricklayer's scaffolding the ledgers support the outside ends of the putlogs. (See Bearers.)

Bearers

Bearers are the horizontal members upon which the scaffolding planks rest and in a bricklayer's scaffolding are known as putlogs.

Scaffolding planks

Scaffolding planks are the horizontally placed boards which rest on the bearers, or putlogs. Scaffolding planks are usually of oregon but other timbers may be used, provided they are sound and not used over large spans. The ends of scaffolding planks are usually bound with hoop iron to prevent cracking or splitting.

Guard rails

Guard or hand rails are the horizontal members placed about 3 ft. above the scaffolding planks on a scaffolding more than 10 ft. above the ground. A timber scaffolding usually has 3 in. x 2 in. guard rails.

Braces

Braces are the diagonal members of a scaffolding used to brace the structure rigidly.

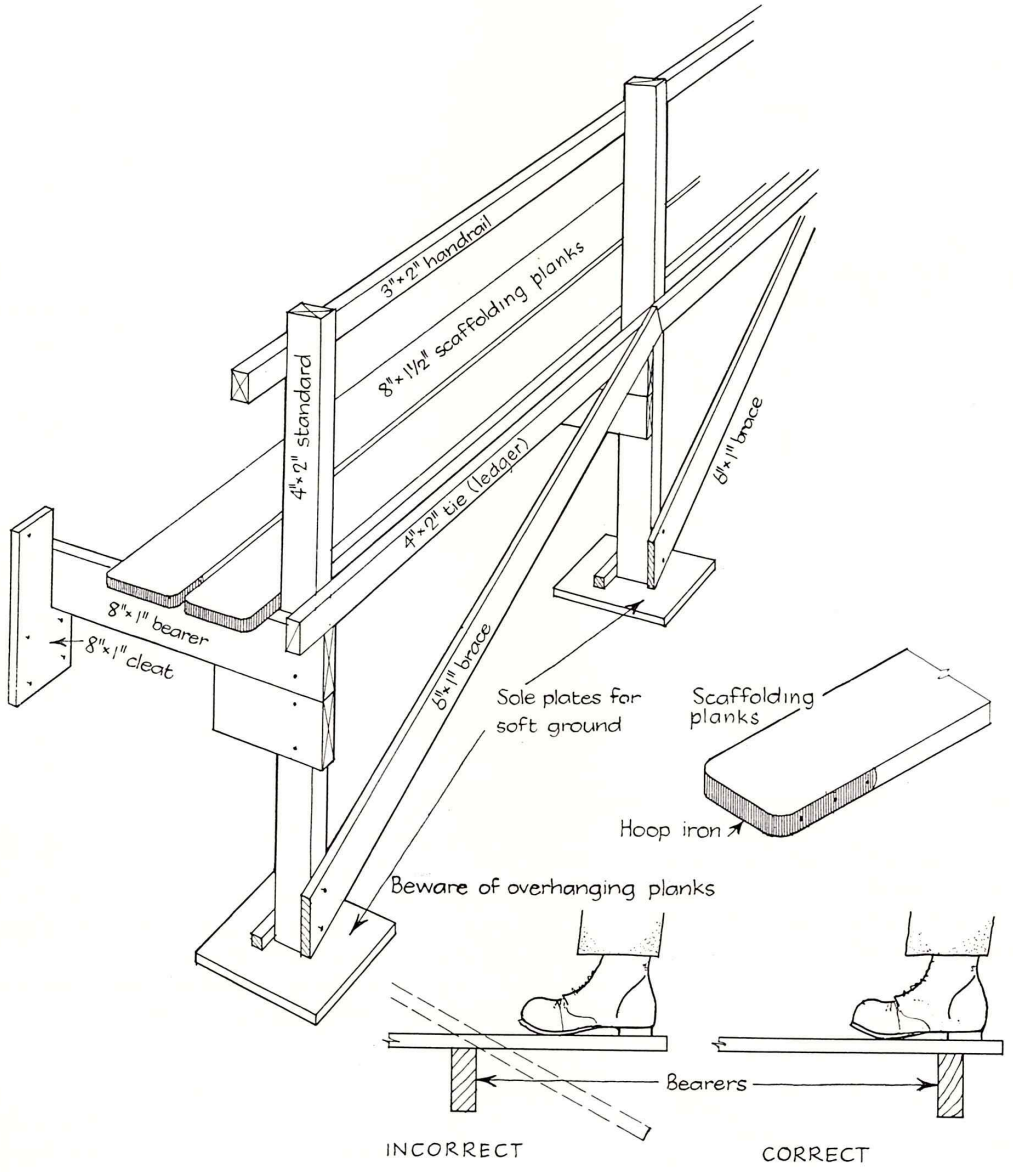


Fig. 379 *Simple wooden scaffolding*

Fixings

Although members of timber scaffolding may be bolted together in the usual manner, the use of U bolts (*Fig.* 380) is popular because holes for the bolts are not necessary and dismantling is made easier. Light scaffolding are frequently nailed together with supporting cleats under the bearers.

Scaffolding for low work (*Fig.* 381)

The scaffolding used in residential construction work is often a simple arrangement of standards and bearers, but very frequently adjustable steel or wooden trestles are used to support the scaffolding planks. This scaffolding may be erected or dismantled quickly and is equally suitable for inside or outside work provided the ground is reasonably level.

Bracket scaffolding (*Fig.* 382)

Brackets made of either wood or steel are frequently used on the exterior of buildings to support scaffolding planks. The metal brackets are securely fastened to the wall by screw-eye bolts fixed into the studs, while the wooden type of bracket is held against a wall by means of a diagonal strut.

Timber scaffolding for timber-framed building (Fig. 379)

External scaffolding for carpenters is constructed to the following specification:

Standards are spaced at intervals depending upon the size of planks and should be of 4 in. x 2 in. timber up to 15 ft. in height.

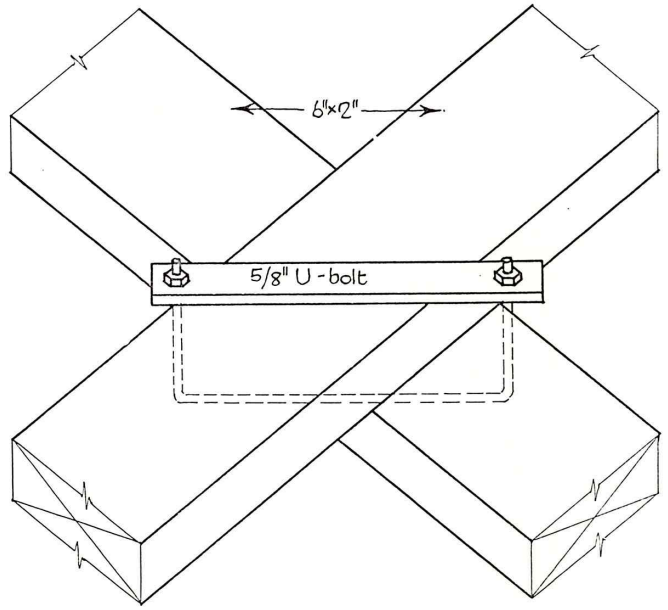


Fig. 380

U-bolts

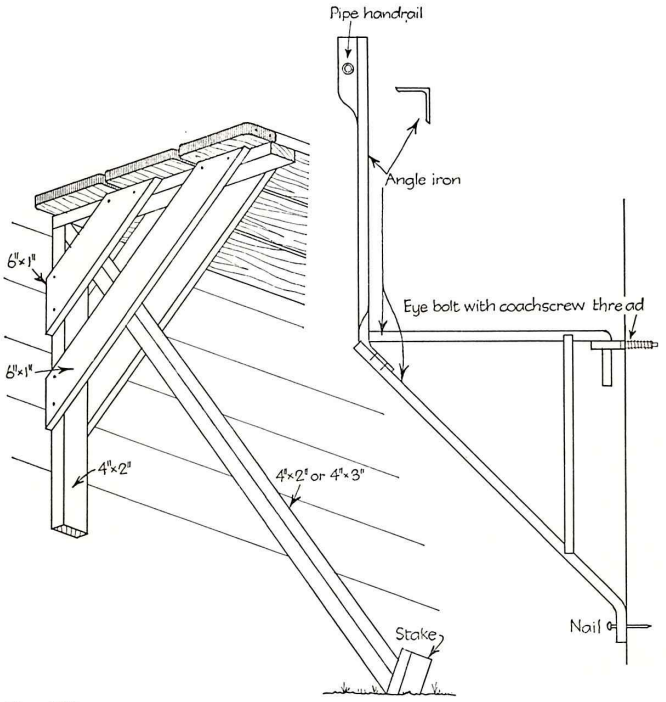


Fig. 382

Types of bracket scaffolding

Standards should rest on a sole plate or other solid support.

Bearers and cleats should be of not less than 6 in. x 1 in. timber, securely nailed to walls and standards.

Scaffolding should be well braced with 6 in. x 1 in. braces securely nailed to standards.

Dismantling timber scaffolding

The rough handling of timbers during the dismantling of scaffolding can cause fractures which may not be revealed until the timber is used for scaffolding on a later occasion. It is important, therefore, that such timbers should be handled with care.

Nails should be extracted and the material cleaned and stored away for future use.

Steel scaffolding

Steel has largely superseded timber for scaffolding, as it is quicker to erect and dismantle than timber, and is not so liable to damage. There are two kinds of steel scaffolding:

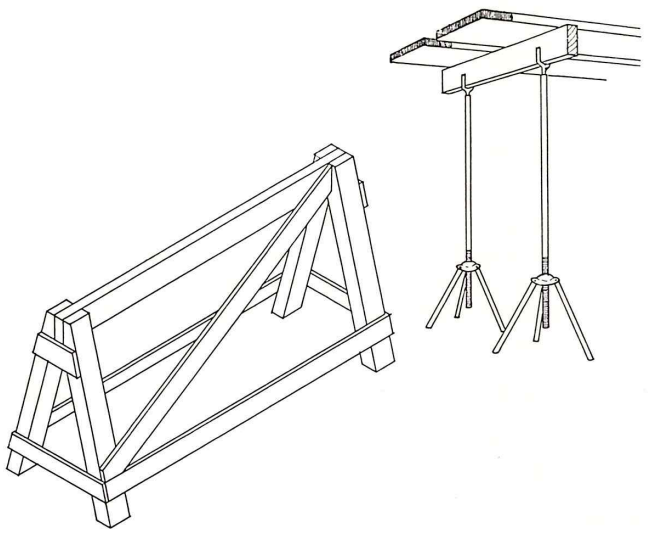


Fig. 381

Two types of trestles

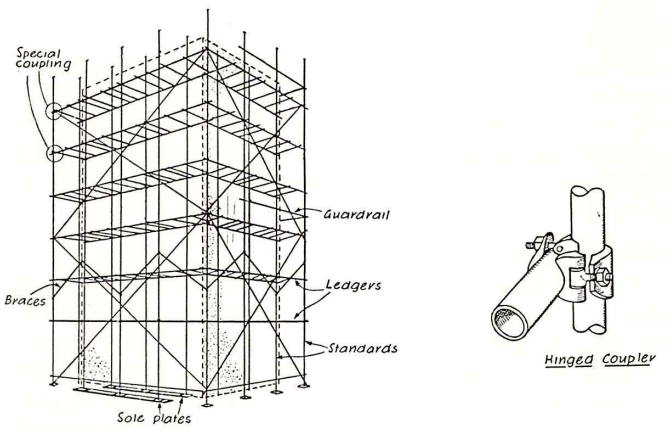


Fig. 383

Tubular-steel scaffolding

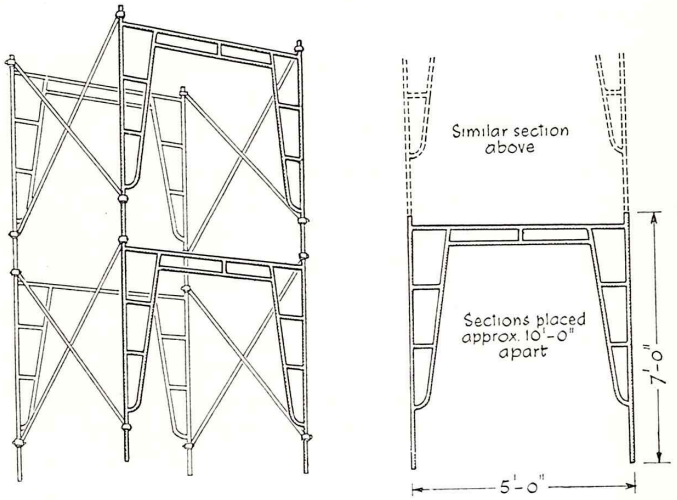


Fig. 384

Freestanding scaffolding

(1) *Tubular-steel scaffolding* (*Fig.* 383)
This is erected in a manner similar to timber scaffolding in that it is composed of standards, putlogs, ledgers, braces, etc. Tubular scaffolding is joined together with specially made couplings which are tightened up with a spanner.

(2) *Freestanding scaffolding* (*Fig.* 384)
This type of scaffolding comprises tubular frames which fit into one another. It is extremely simple, quickly erected, and lighter in construction than tubular-steel scaffolding.

Ladders (*Fig.* 385)

A ladder is a framework consisting of two parallel or nearly parallel pieces of timber known as stiles, connected at regular intervals by cross pieces of timber (rungs) which serve as steps in climbing to different levels.

The timber for a ladder must be clean, straight-grained, and free from defects. Oregon is a suitable timber for stiles, and hardwoods such as spotted gum, treated tawa, or beech, for rungs. The rungs of ladders may be of circular shape fixed into holes in the middle of the stiles, or of rectangular pieces checked into the front edges of the stiles. The stiles of ladders should be tied together with $\frac{1}{4}$ in. steel bolts fixed under each end rung and at intervals along the ladder.

Use of ladders

For convenience and safety the foot of a ladder should rest on a firm non-slip base and the ladder should be at an incline which is comfortable to climb, i.e., approximately 1 in 4. The top of a ladder should extend at least 3 ft. above the level of a scaffolding so that a convenient hand-hold is provided when one is stepping from the scaffolding to the ladder. One should always face a ladder when either ascending or descending.

Ladders placed in streets should be protected against being knocked down and in windy weather they should be properly secured so that they may not be blown down.

***Excavations* (*Fig.* 386)**

The Construction Regulations require that the sides of any excavations must be shored and timbered while there is danger to any person.

All timbers used for sheeting and poling boards must be in a sound condition, and other timbers of the required dimensions of sound, straight timber, free from defects such as cracks, shakes, and large loose knots.

Trenches that have to be timbered and are over 5 ft. in depth and more than 8 ft. long must have the sides supported by poling boards and struts. When the sides of the trenches are of compact material, they should be braced at 8 ft. intervals with 6 in. x 2 in. poling boards placed vertically and opposite each other, and supported by either screw jacks or struts.

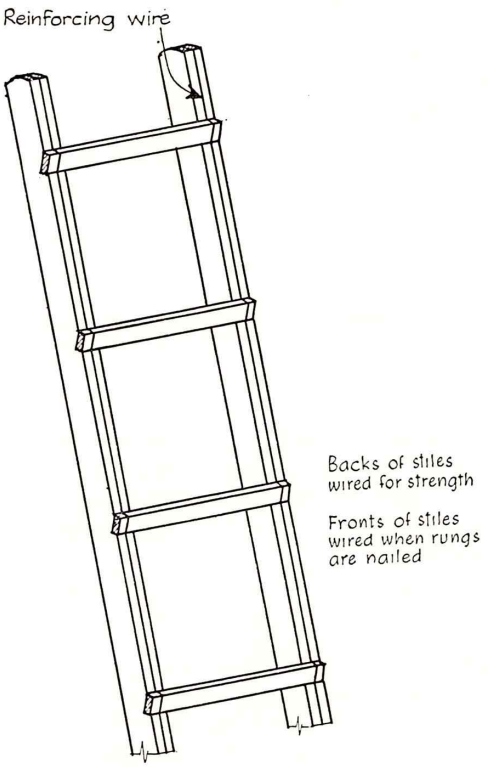


Fig. 385

Typical wooden ladder reinforced with wire

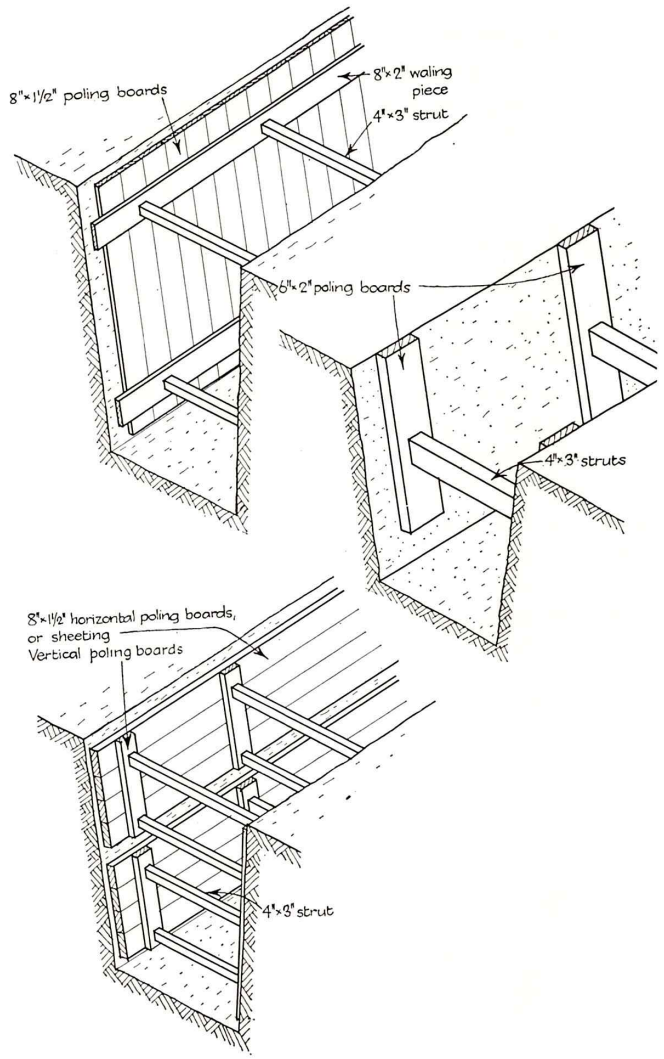


Fig. 386

Typical methods of timbering excavations under 5 ft. in depth

When trenches are made in saturated, filled, or unstable ground, the poling boards must be placed close together, i.e., close timbered, and must be of 6 in. x 2 in. timbers supported by 6 in. x 4 in. walings held by struts or screw jacks.

The sides of trenches in running material are supported with tongued and grooved poling boards.

Timbering should be done in such a manner that the supports in the trenches do not unduly interfere with the work being carried out, and also placed so that it may be readily removed. The reader should note carefully the names given to the various members and also the methods of timbering trenches under 5 ft. in depth as shown in *Fig.* 386.

Slinging timber (*Fig.* 387)

It is important that the slinging of timber should be done carefully and intelligently, as there have been many accidents through materials falling from slings.

The most important knot used in this connection is the *timber hitch.* This knot when tied to a single piece of timber or to a number of pieces will tighten as the pull is applied. The timber hitch may be adapted to hoist timber vertically.

Further information on the Construction Regulations can be found in "Safety in Construction No. 3 Scaffolding Guide". This book has been prepared by the office of the Chief Safety Engineer, Department of Labour.

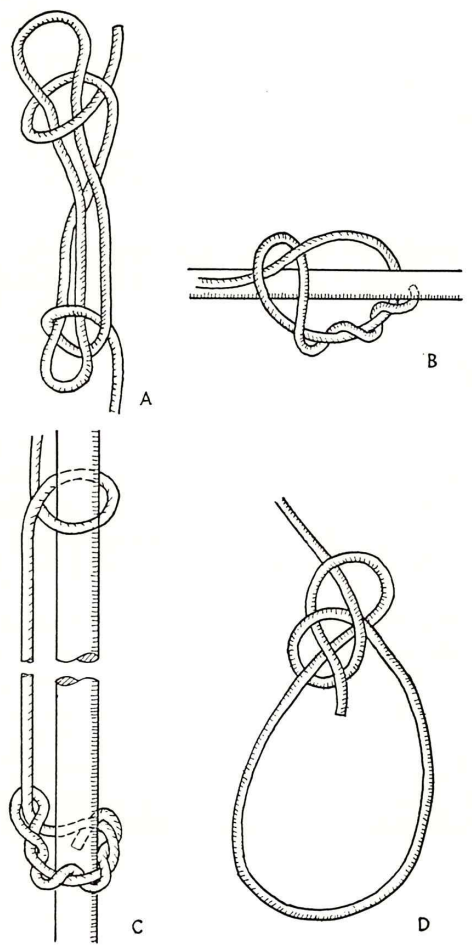


Fig. 387

Useful knots

(A) *Sheepshank*
(B) *Timber hitch*
(C) *Half hitch and timber hitch applied to hoist vertically*
(D) *Bowline*

Bowline
This knot is used when it is required to make a loop which will not slip.

Sheep shank
When it is necessary to shorten a rope without cutting it, the sheep shank may be used.

Size of ropes
Rope is measured by the circumference and not by the diameter so that a $1\frac{1}{2}$ in. rope would be just under $\frac{1}{2}$ in. in diameter.

Questions on Chapter 14

(1) (a) What is the purpose of scaffolding?
(b) Under what conditions is it necessary to take out a permit for scaffolding or an excavation?

(2) A timber-framed building is in the process of being sheathed with weatherboards and the work has reached a stage where scaffolding is necessary. Sketch the kind of timber scaffold you would erect, and name the various parts of the scaffolding.

(3) Describe the various kinds of steel trestles that may be used during the erection of the average dwelling.

(4) There are certain precautions to be observed when erecting scaffolding and also when dismantling. What are these precautions?

(5) (a) How is a ladder strengthened?
(b) What safeguards would you take if you had to use a ladder in a public place?

(6) How would you hold up the walls of an excavation 5 ft. 6 in. in depth and 12 ft. long? Assume that the ground is soft.

Calculations

(1) What is the percentage increase of a carpenter's wage if his hourly rate is raised from 6s. to 6s. 8d. per hour?

(2) Calculate the cross-sectional area of round steel reinforcing rods of the following diameters:
(a) $\frac{3}{8}$ in.
(b) $\frac{1}{2}$ in.
(c) $\frac{5}{8}$ in.

(3) Estimate the cost of painting the walls and ceiling of a room 16 ft. long, 12 ft. wide, and 8 ft. high at a cost of 4s. 6d. per square yard for the walls and 6s. 3d. per square yard for the ceiling. Allow an area of 24 sq. ft. for windows.

(4) A cylindrical roof tank holds 30 gallons of water when the water is 2 ft. deep in the tank. Calculate:
(a) The diameter of the tank.
(b) The circumference (1 cu. ft. $= 6\frac{1}{4}$ gal.)

(5) In building a platform, 195 boards $4\frac{1}{2}$ in. wide are used. How many $2\frac{1}{2}$ in. wide boards would be used to build a similar platform?

Chapter 15

FORMWORK FOR CONCRETE

Concrete carpentry is the fabrication of timber structures used in the placing of concrete. Such a structure is of a temporary nature and is really a mould in which concrete is placed, and which is removed when the concrete has attained sufficient strength. These moulds are known by the several names of formwork, falsework, shuttering, or boxing.

Timber formwork

Radiata pine is by far the commonest timber for formwork but other timbers such as rimu, miro, and kahikatea are at times used. Such timbers should be free from large knots. Partially seasoned timber is preferable to either wet or dry timber, because dry timber will swell from absorption of moisture from the concrete, and green or wet timber will dry out and shrink in hot weather, thus making crevices which may allow the cement paste to escape and also cause ridges in the set concrete.

Purposes of formwork

Formwork should fulfil the following purposes:

(1) It must provide a rigid mould to retain the concrete until is has hardened.

(2) It must be free from gaps or loose knots through which wastage could occur.

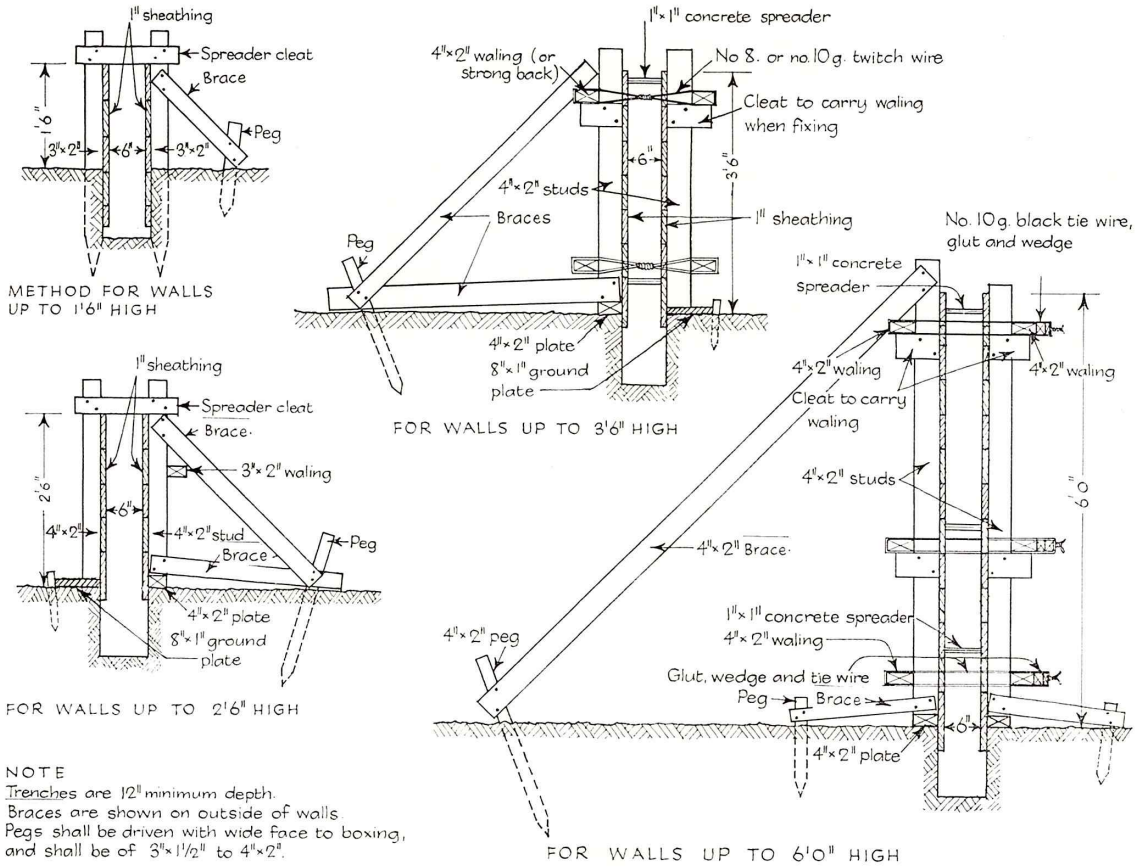
(3) It must not be too absorbent.

(4) It must not allow the concrete to adhere to its surface.

(5) It must be built so that it may be dismantled without damage to either the formwork or the concrete.

Construction of formwork

Formwork consists of a rigidly braced timber structure faced with boards or with panels known as shuttering. The following is a description of the various structural and other timbers used for formwork. (See *Figs.* 388 and 389.)



NOTE
Trenches are 12" minimum depth.
Braces are shown on outside of walls.
Pegs shall be driven with wide face to boxing, and shall be of 3"×1½" to 4"×2".

Fig. 388

Formwork for low walls

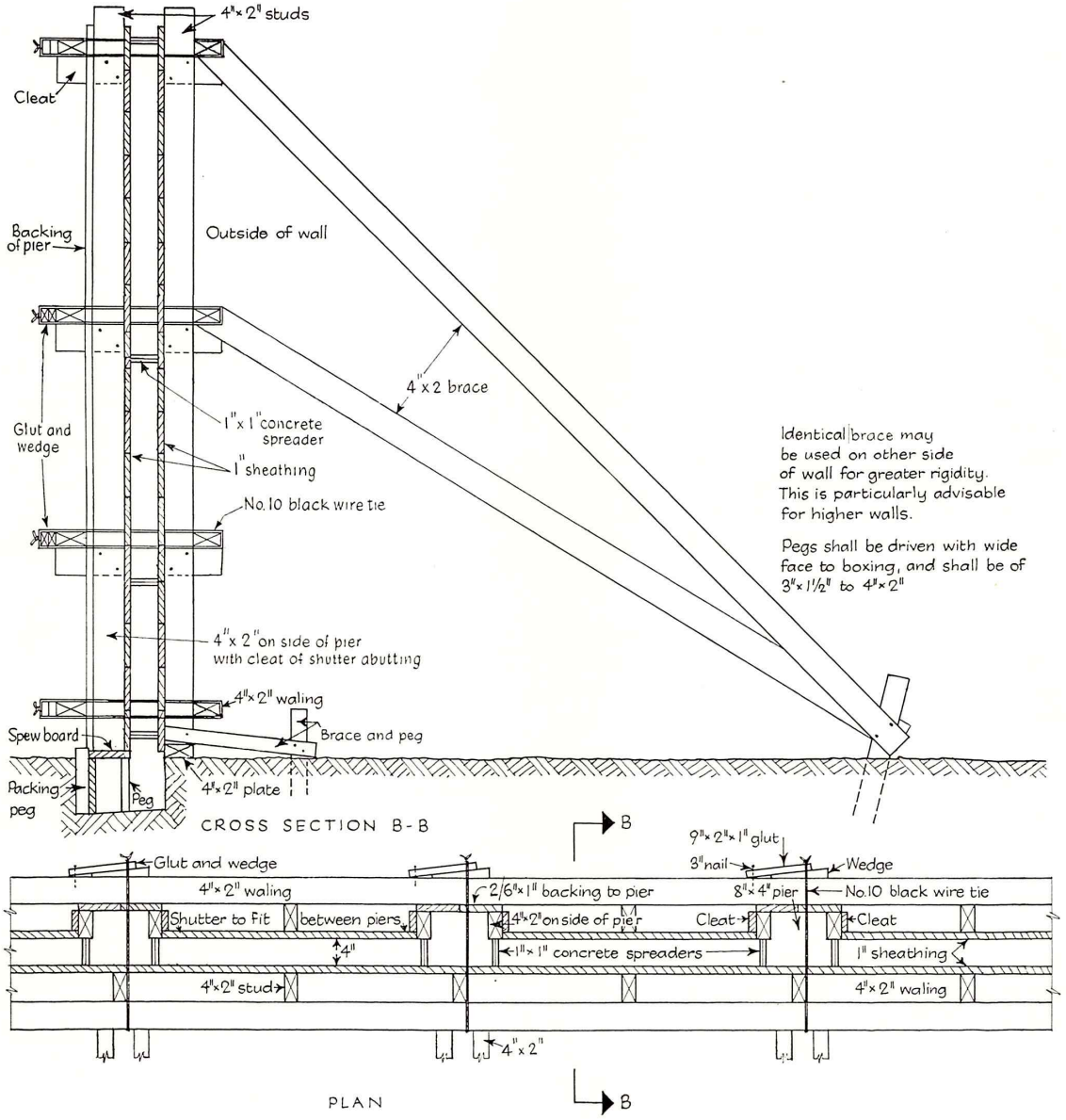


Fig. 389

Formwork for high walls

Ground plate

A ground plate is a scantling timber, fixed to the ground by pegs, for the purpose of supporting the formwork.

Studs

The studs are the vertical framing timbers of 3 in. x 2 in. or 4 in. x 2 in. spaced according to the height of the wall and the thickness of the sheathing. Standard spacing is about 2 ft. centres with 4 in. x 2 in. studs. These studs are sometimes called profiles, because they outline the vertical shape or contour of a wall, and should not be confused with the profiles used in foundation work.

Sheathing

The closely jointed boards fixed to studs are known as sheathing. The thickness varies from $\frac{1}{2}$ in. to $1\frac{1}{2}$ in. but is usually 1 in. Sheathing timbers may be rough-sawn or dressed, or tongued and grooved, but timber gauged to a thickness provides good results.

Where the finished surface of the concrete is to be smooth, dressed tongued and grooved timbers or sheets of resin-bonded plywood should be used as sheathing to produce a fine finish. On the other hand rough-sawn boards provide a rough surface and consequently give a key for subsequent renderings of cement stucco.

Shuttering (*Fig.* 390)
Shuttering is a type of formwork composed of framed metal or timber panels that are movable for the successive lifts in concrete work. A shutter is usually a frame of 3 in. x 2 in. or 4 in. x 2 in. timber sheathed with resin-bonded plywood, hardboard, ordinary boards or sheet metal over a solid timber backing. Nowadays 8 ft. x 4 ft. x $\frac{3}{4}$ in. sheets of resin-bonded plywood are extensively used as a facing material for shutters.

Walings
Walings are the horizontal timbers secured to the vertical framing of shutters or sheathing to stiffen and tie them together. Where height allows, walings are spaced at about 3 ft. intervals and within 1 ft. of the top and bottom of a wall. Walings may be of 4 in. x 3 in. or comprise two 4 in. x 1 in. pieces of timber with 1 in. packing pieces separating them. The latter type of waling has the advantage of being light in weight and bolts may be placed in any position in the waling without the boring of holes which must be made in a solid waling.

Bracing
Bracing is used to stiffen the formwork and comprises braces of either 4 in. x 3 in. or 4 in. x 2 in. timbers secured at regular intervals to the walings and to stakes in the ground. Braces should be of sound timber free from defects.

Erection of formwork
Formwork should be erected in accordance with the drawings prepared by the architect. Such work should be true to line and solidly braced to prevent deformation under the weight and pressure of the concrete.

Methods of tying walls
The formwork of walls is tied together with wire, bolts, or patent devices, and the walls are kept apart by wood, metal, or concrete spreaders.

Use of wires
The wire for tying wall formwork may be No. 8, 9 or 10 S.W.G. black annealed wire. These wires may be twitched, or gluts and wedges may be used to tighten them. The latter method is preferable because a twitched wire is inclined to slacken under the weight of the concrete against the formwork. *Fig.* 391 shows the method of twitching wires and the use of gluts and wedges is shown in *Figs.* 389 and 392.

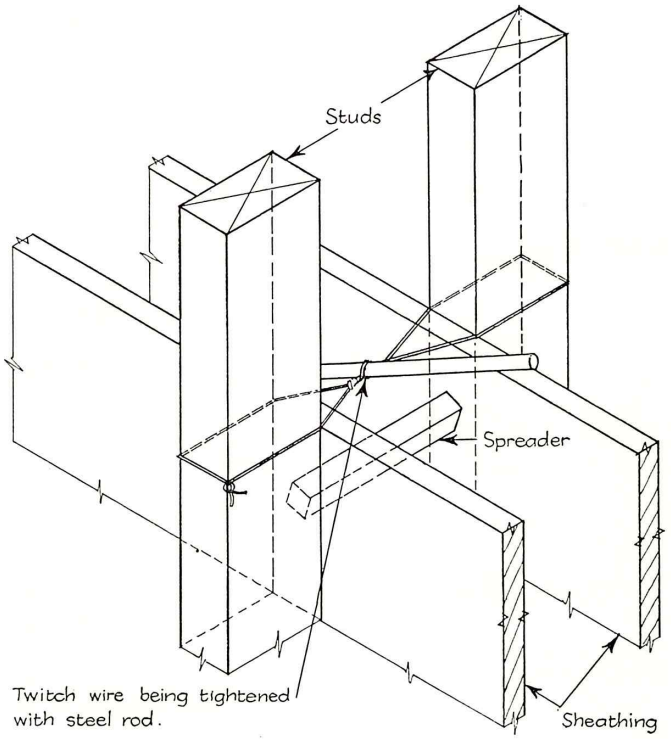


Fig. 391

Illustration shows wire being twitched with steel rod

Bolting of formwork
Bolts with washers and nuts in sizes from $\frac{1}{2}$ in. to $\frac{3}{4}$ in. and usually with square heads and nuts are generally used in heavier wall construction. When bolts are to be drawn after use they must be well greased or fitted

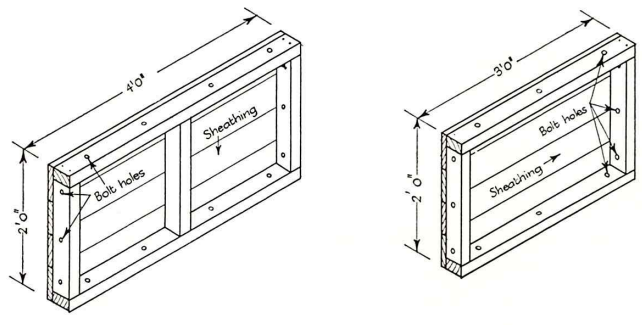


Fig. 390

Types of shutters

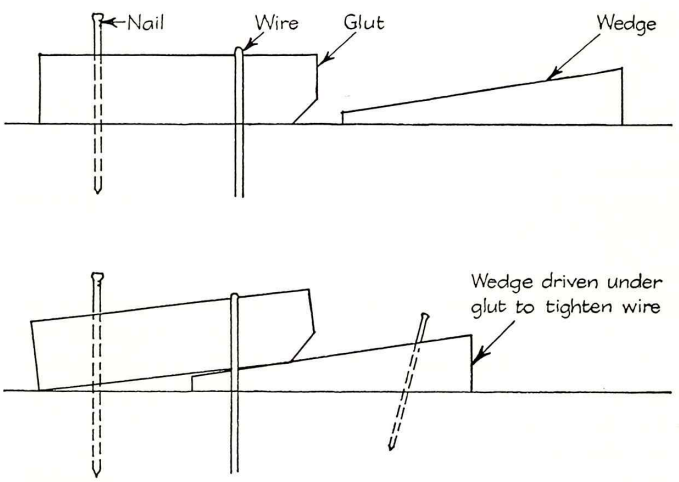


Fig. 392

Gluts and wedges

with sleeves. A description of patent devices available for this purpose is beyond the scope of this work.

Spreaders

Spreaders are short lengths of wood, concrete, or metal fixed between the faces of shuttering to keep them separated to the thickness of the wall before the concrete is placed. Pre-cast concrete spreaders often have a $\frac{3}{4}$ in. hole through the centre of each spreader for a bolt. An advantage of concrete spreaders is that they may be left in a wall but wooden or steel spreaders must be removed as the concrete is placed.

Holding-down devices (*Fig.* 393)

Timber wall plates are secured to concrete walls by means of $\frac{3}{8}$ in. bolts or pieces of $\frac{3}{8}$ in. reinforcing rods embedded in the concrete.

When a piece of reinforcing rod is used it is known as a dowel. One end must be embedded at least 6 in. in the concrete and bent in the shape of a hook like the end of a reinforcing rod. Bolts must be embedded at least 3 in. in concrete and it is usual to kink the shank of the bolt so that it is impossible to turn it under any circumstances. These holding-down bolts are spaced at 4 ft. 6 in. centres and the top ends kept higher than the top of the wall plate to allow for nuts to be screwed on. The top ends of dowels are clinched over, recessed flush on the top of the wall plates, and stapled.

To hold the dowels or bolts in place until the concrete is placed, straps bored for the bolts are fixed across the top of the boxing at 4 ft. 6in. intervals.

Fixing joinery in concrete walls

Door and window frames are placed in the formwork either to the inside or outside of the wall, as circumstances demand, and tested for level and plumb before being secured to the sheathing. Struts are placed in appropriate positions to prevent the frames being deformed under the weight of the concrete.

Frames are permanently secured to the concrete by either metal lugs fixed to the back of the frame or by driving pieces of hooked reinforcing rod into the back of the frame. Sometimes partly driven 4 in. nails are used instead of reinforcing rods. Joinery is often secured to the concrete after the formwork has been removed, but in such circumstances provision for securing the fittings is made by arranging bolts, metal lugs, or durable wooden strips in the concrete. Strips of wood (*Fig.* 394) are dovetailed in shape and are nailed to the sheathing in appropriate positions. Parts of joinery frames in contact with concrete should be painted with red lead.

Oiling of shutters and sheathing

The surface of shutters and sheathing in contact with wet concrete should be oiled or coated with a substance that will prevent the concrete adhering to the surface. If an oil is used care must be taken that it does not cover any of the reinforcement.

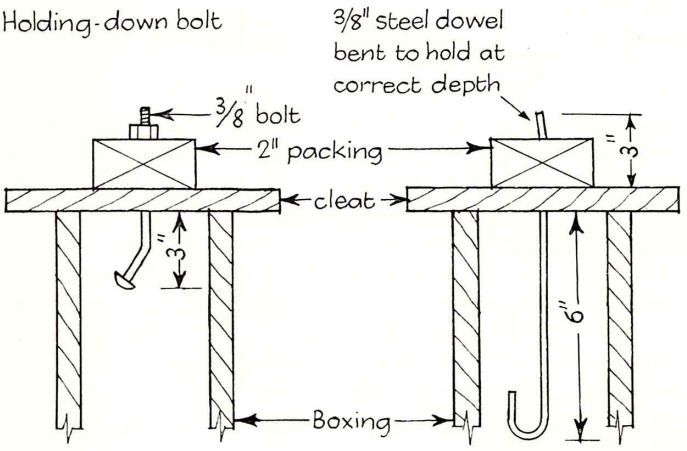


Fig. 393

Holding-down devices

Final inspection of formwork

Before leaving the work a check should be made of the following:

(1) All the formwork should be true to line and rigidly braced and strutted.

(2) Joints should be tight to prevent any leakage or cement grout.

(3) Spreaders should be checked for number and position.

(4) Tie wires, bolts, and other fixings should be tight and secure.

(5) All the fillets for chamfered edges, the dovetailed nailing strips, and inserts for openings and recesses must be in place and secured to the formwork.

(6) Reinforcing steel should be rigidly tied so that it will not move out of position during the placing of the concrete.

(7) It is important to note that the clearance between the steel and the formwork is such that the steel has the necessary concrete cover.

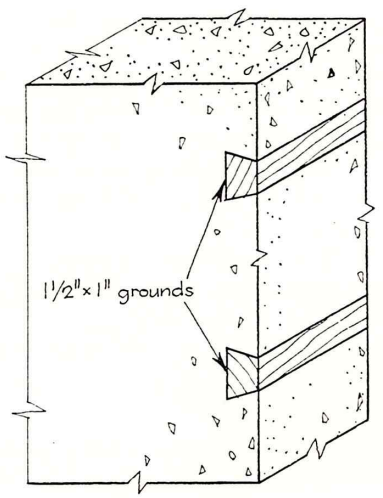


Fig. 394

Dovetailed nailing fillets

(8) Any chips and blocks of wood, or debris in the formwork should be removed before the concrete is placed.

Removal of formwork (see also page 236)

Formwork is removed when the concrete has hardened and attained sufficient strength to avoid injury and, in the case of a beam, to support its own weight. In temperate weather the formwork on beam sides and walls may be removed two to three days after the concrete has been poured if normal Portland cement has been used in the concrete. See N.Z.S.S 95, Part V, Formwork. As concrete hardens more slowly at low temperatures, formwork is left in place for longer periods in colder weather. All formwork should be removed by gradual easing away from the concrete without jarring or injuring it in any way.

Erection of formwork for concrete foundation walls

Stud and sheathing method (Figs. 388, 389)

When the shape of a building has been pegged out and the profiles and building lines fixed, the next job is to prepare the formwork. Ground plates are laid (plumb from the building line), straightened, and secured by pegs and braces 4 ft. apart.

The foundation trenches are now dug, using the edges of the ground plates as a guide.

In many cases, in order to prevent the collapse of the excavation, some concrete is placed immediately the reinforcing steel for the footing is fixed.

The formwork is then erected in the manner described below. It is usual to commence with an outside wall.

(1) At each end of a wall erect a stud (to the inside edge of the ground plate) plumb and braced both ways.

(2) Erect intermediate studs and attach walings placed at heights necessary for the particular wall.

(3) Fix the sheathing to the studs; then straighten the wall and secure braces (from pegs in the ground to walings). The top of the concrete wall is now determined and marked by a row of nails on the inside of the wall.

(4) Boxes may now be placed for ventilation openings and for any pipes that will pass through the wall. Nailing strips for door or window frames can be placed or the actual frames themselves put in position, plumbed, and secured against the sheathing.

(5) The reinforcing steel may now be fixed and tied securely so that it will not shift when the concrete is placed.

(6) The inside wall is erected in much the same way as the outside wall, except that the sheathing must be skew nailed into the studs. An alternative method is to fix the sheathing to the studs lying in position on the ground and then raise the wall to the vertical position in one operation.

Note: There is not always sufficient space to skew nail sheathing to the studs and in these instances, the boards must be held in place, with a lever from an existing wall, and then skew nailed through the sides of the studs into the backs of the boards.

(7) The formwork now is bored for the tying wires and when the spreaders have been placed between the walls, at points of solid bearing, the wires can be tightened by one of the methods described on page 220. Low walls are at times kept apart by a spreader cleat or strap across the top of the boxing.

Use of shutters (Fig. 395)

The shutters for a wall are first set up on the ground plates and then bolted together. If nails are used *do not drive them home.* Walings may now be fixed and the wall, plumbed, straightened, and braced in the usual manner.

The erection of the inside wall is carried out in a manner similar to that just described for the outside wall, the inside wall being tied to the outside one by one of the methods described.

Formwork of piles

Pile formwork may be constructed either out of four pieces of 9 in. x 1 in. or out of short lengths of timber nailed to the edges of 8 in. x 1 in. boards which are spaced 8 in. apart. Both methods give an internal measurement of 8 in. x 8 in.

The formwork is placed in the hole dug for the base of the pile, raised to the correct height, and secured in position. One method of securing pile formwork is shown in *Fig.* 396.

Concrete steps (Fig. 397)

Well designed steps should be easy to ascend and not take up too much space. In order to accomplish this, the going and the rise of steps should bear a definite relationship to each other. A rule which gives a satisfactory ratio between the rise and the going of a step is: going plus twice the rise should equal 23 to 24 in.

Example: Each step in a flight has a going of 11 in. and a rise of 6 in. Will such a flight of steps be satisfactory?
Rule: G + 2R = 23 to 24 in.
As 11 in. + 12 in. = 23 in., the flight will be satisfactory.

Concrete steps usually have a going of 12 in., and a rise of between $5\frac{1}{2}$ in. and 6 in.

Setting out steps

When setting out a flight of steps it must be borne in mind that in each flight there is always *one more riser than there are treads.*

If a flight of concrete steps had to be set out for a front entrance, the first operation would be to determine the total rise of the flight. This rise would then be divided by $5\frac{1}{2}$ in. to give the number of risers.

Example: Find the rise and going of each step in a concrete flight of steps if the total rise is 4 ft. $5\frac{1}{2}$ in. Determine also the total going.

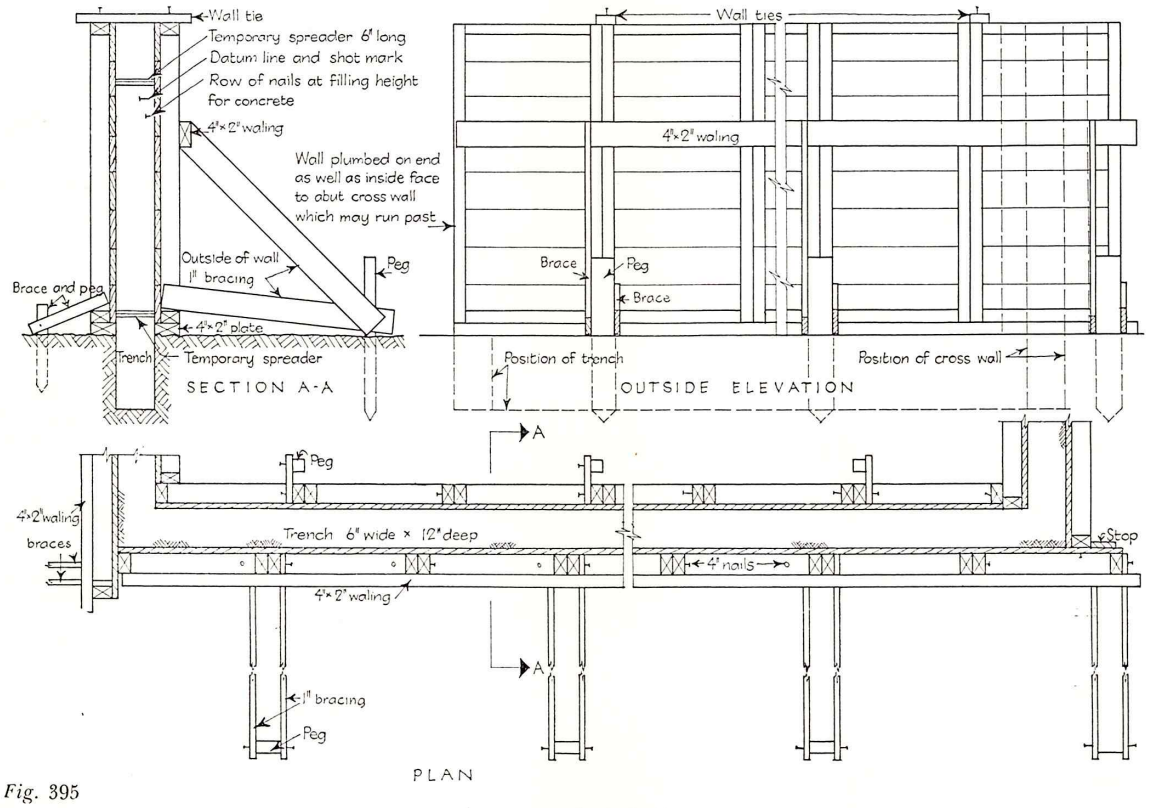


Fig. 395

Arrangement of shutters

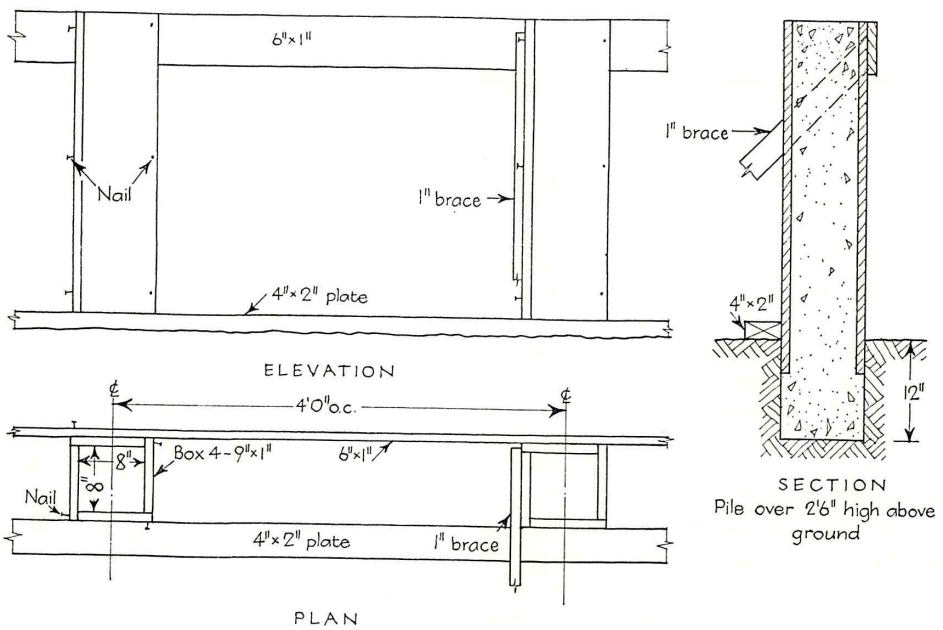


Fig. 396

Formwork for piles

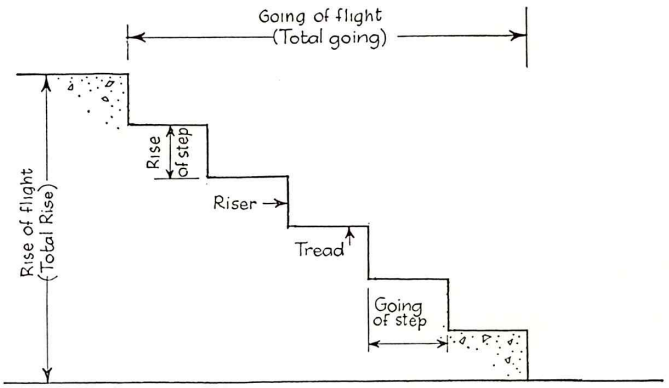


Fig. 397

"Rise" and "going" of a flight of steps

$$\text{No. of risers} = \frac{4 \text{ ft. } 5\frac{1}{2} \text{ in.}}{5\frac{1}{2} \text{ in.}}$$

$$= \frac{53\frac{1}{2} \text{ in.}}{5\frac{1}{2} \text{ in.}}$$

$$= \frac{107}{2} \times \frac{2}{11}$$

$$= 9\frac{8}{11} \text{ risers.}$$

The number of risers will be 9 and each will be more than $5\frac{1}{2}$ in.

$$\text{Rise of step} = \frac{4 \text{ ft. } 5\frac{1}{2} \text{ in.}}{9}$$

$$= \frac{107}{2} \times \frac{1}{9}$$

$$= 5\frac{17}{18} \text{ in.}$$

Total going would be the number of treads multiplied by the going of 1 tread.

$$= 8 \text{ x } 12 \text{ in.} = 8 \text{ ft.}$$

If the space for the steps were restricted, a narrower going of, say, 10 in. would be necessary. In order to comply with the rule the rise would then need to be between $6\frac{1}{2}$ in. and 7 in. This arrangement would give a total of 8 risers and 7 treads with a total going of only 5 ft. 10 in.

The actual setting out of the strings for a flight of steps is shown in *Fig.* 398. A steel framing square or a margin template and pitch board may be used. A pitch board is a thin triangular piece of board of plywood the shape of a right-angled triangle, with the sides of the triangle to the dimensions of the going and the rise of a step. The pitch board is used with the margin template as shown. *Fig.* 398 shows how the strings are arranged as a pair, and the steps set out on one side, the marks squared across the edges of the strings, and the steps then set out on the other side of the strings.

The risers for concrete steps may be arranged by any of the methods shown (*Fig.* 399). The position of the

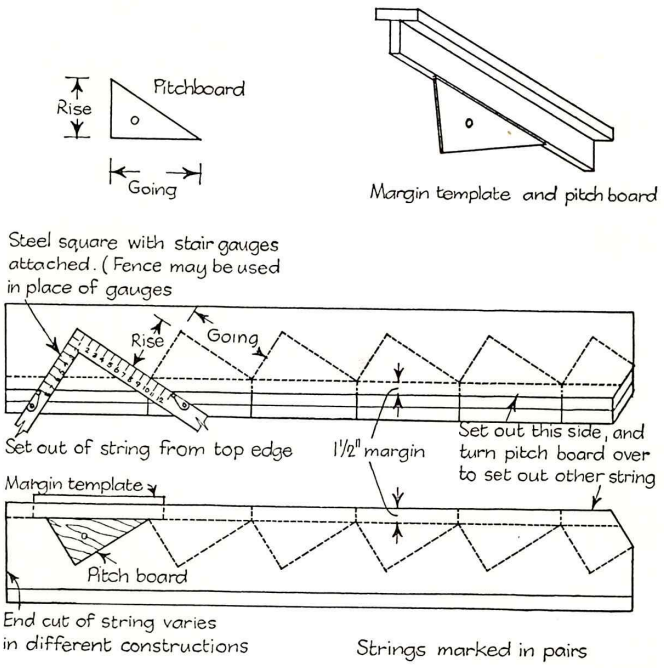

Rise
Pitchboard
Going
Margin template and pitch board
Steel square with stair gauges attached. (Fence may be used in place of gauges
Rise
Going
Set out of string from top edge
1½" margin
Set out this side, and turn pitch board over to set out other string
Margin template
Pitch board
End cut of string varies in different constructions
Strings marked in pairs

Fig. 398

Setting out flight of steps

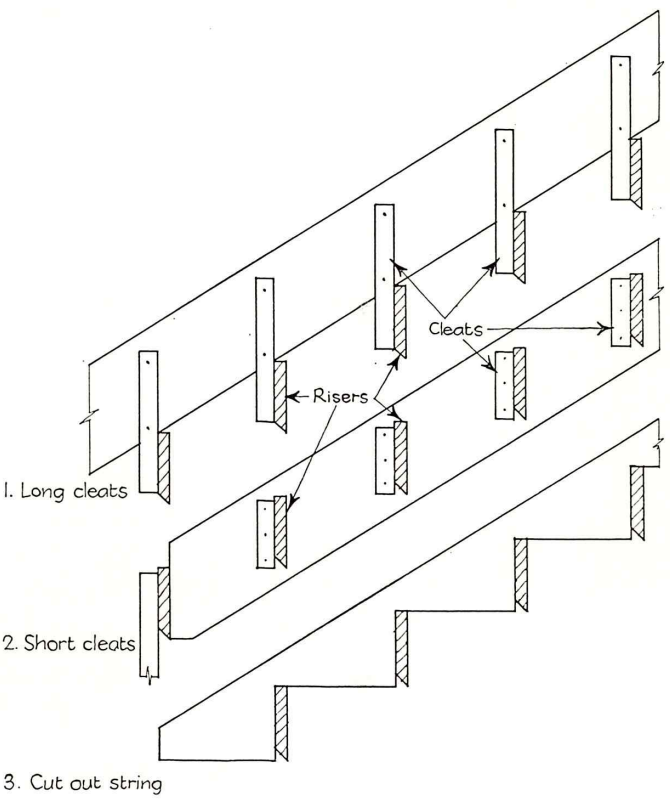


Fig. 399

Three methods of arranging strings for concrete steps

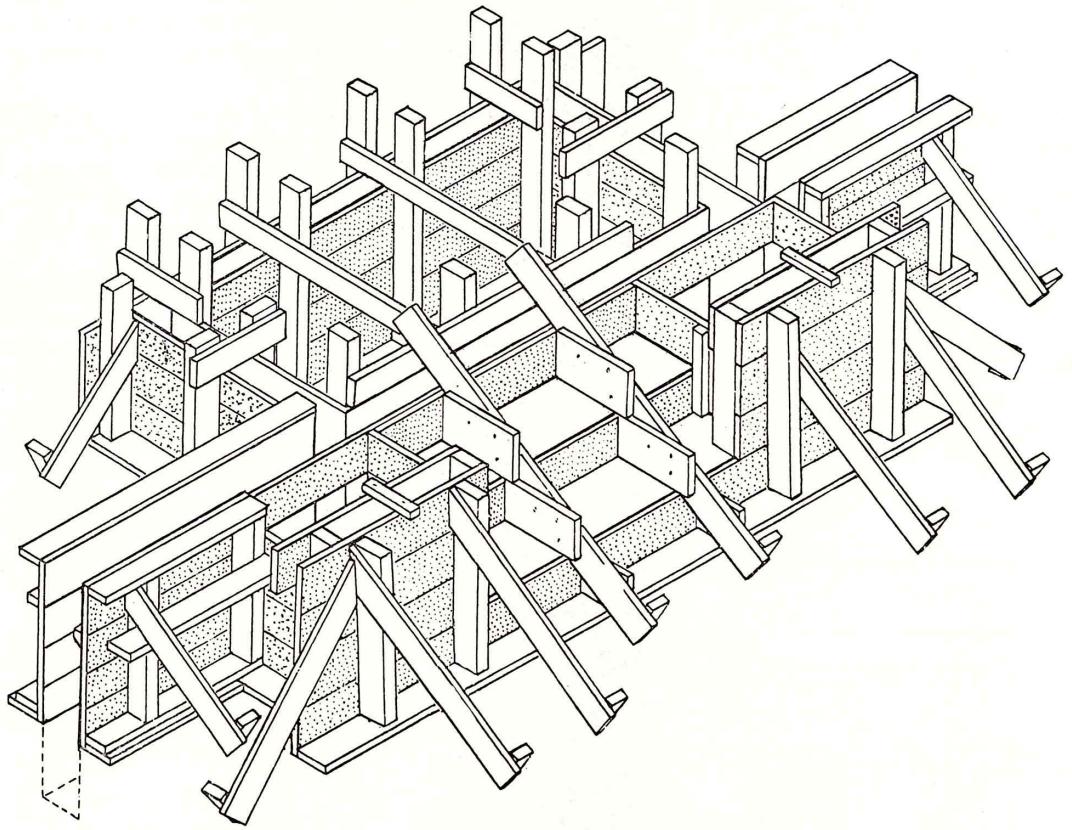


Fig. 400

Arrangement of formwork for solid-core flight of steps

strings decides whether long or short cleats are to be used, and in the third example the "cut-outs" for the steps can be marked from one or other edge of the string.

A slight fall is sometimes given to the tread of each concrete step to run off water. Additional toe room can be made on treads by using sloping risers.

The formwork for a flight of steps and porch is shown in *Fig.* 400, and *Fig.* 401 shows the result when the formwork has been removed. Before the concrete for the porch floor is placed, the space within the low walls at the back of the steps is filled with rock hardfill and the floor cast upon it. This is a "solid filled" floor. When a porch floor is much higher and filling is not practicable, a "hollow core" floor, as shown in *Fig.* 402, is constructed.

Chimney foundations and hearth slab

The chimney foundations and hearth slabs may be formed, as shown (*Fig.* 403), with the reinforcing steel placed as illustrated.

The concrete for the foundation slab is first placed to a depth of about 6 in. and later the boxing for the dwarf walls and cantilevered hearth slab can be put together. This boxing must be supported on wedges to make stripping easy. Shown in *Fig.* 404 is an isometric view of the completed chimney foundation.

Concrete laundry slab

The laundry slab is usually of reinforced concrete supported on dwarf walls or on piles.

An alternative method is to build an enclosure of dwarf walls to take hardfilling and then cast the laundry slab on it.

Reinforcing steel

Reinforced concrete structures are designed to take advantage of the natural properties of concrete and steel. Concrete is strong in compression but very weak in tension. Steel, however, has great tensile strength. In reinforced concrete work, then, we rely mainly on the concrete to take the forces of compression, and on the steel to withstand the forces of tension.

The strength of concrete is therefore dependent upon the correct placing of the reinforcing steel and, as the

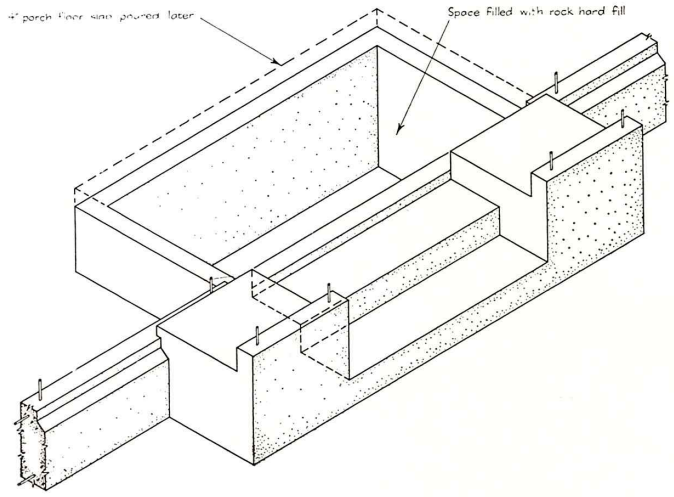


Fig. 401

Solid-core flight of steps

carpenter must surround the reinforcing steel with formwork before the concrete is placed, it is an advantage for him to have some knowledge of steel and its importance in a concrete structure.

Steel is an alloy of iron and carbon and may be divided into three main classes, mild steel, medium steel, and high-tensile steel, according to the amount of carbon present. Mild steel is mostly used for structural and reinforcing purposes and contains up to 0·2 per cent of carbon.

The adhesion or grip between the concrete and steel is of great importance as the two materials are acting together, and, if the adhesion should fail, the steel rods will slip through the concrete. The bond between the two materials must be sufficient to withstand the tendency to separate when the steel is stretched by tension or crushed by compression. Should the steel be covered with mud or have loose scales of rust or be covered with oil or paint, the grip between the concrete and the steel is lessened to a considerable extent.

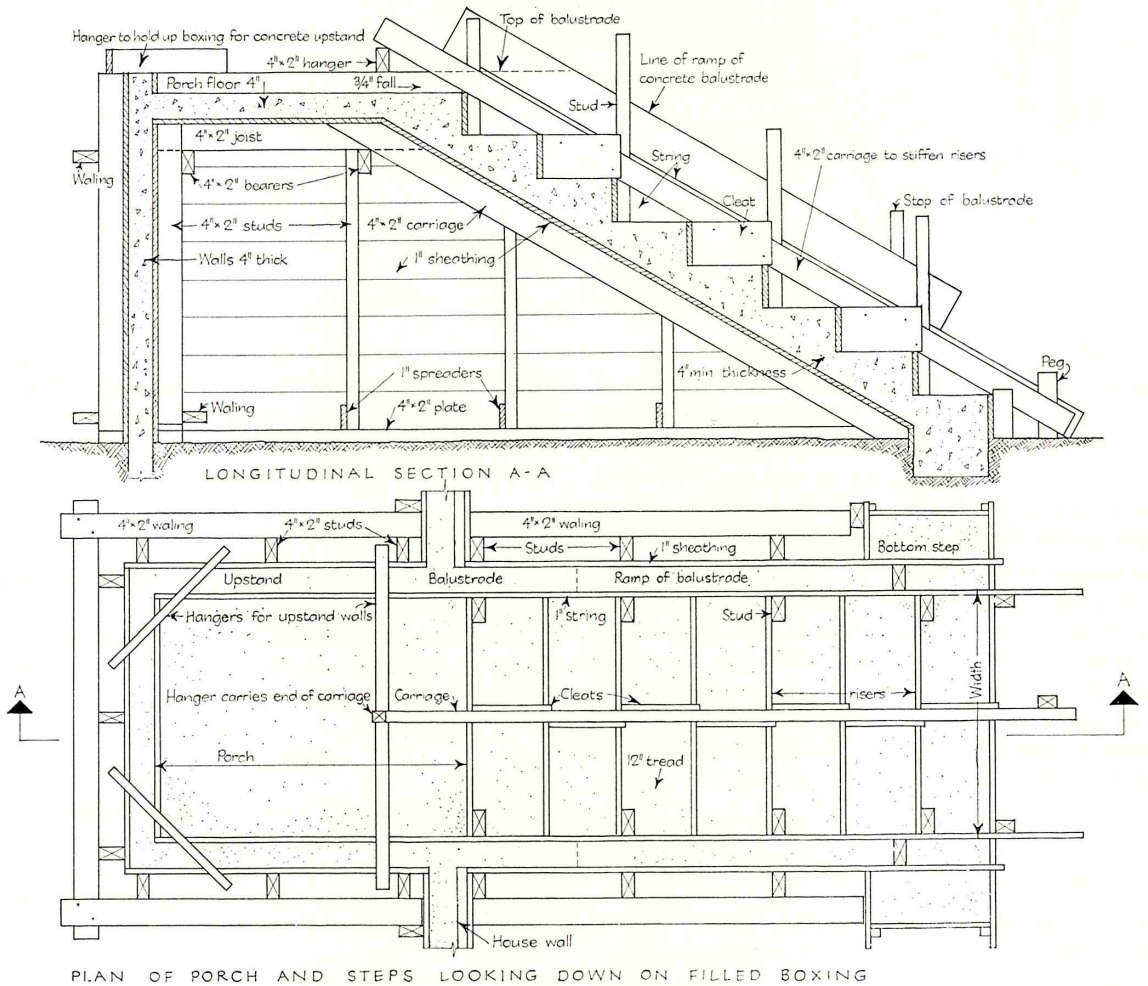


Fig. 402

Hollow-core formwork for flight of steps

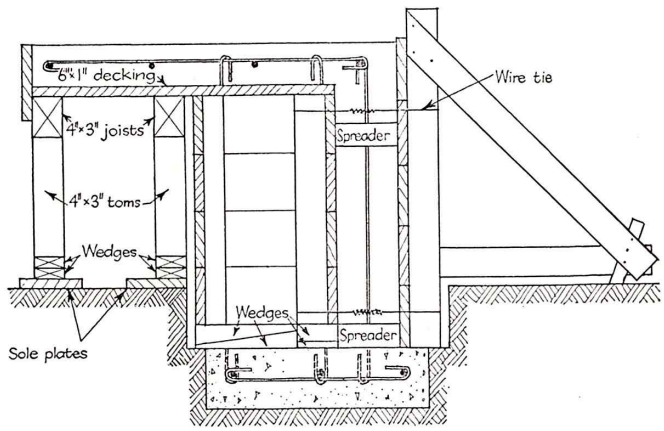


Fig. 403

Formwork for chimney foundation and hearth slab

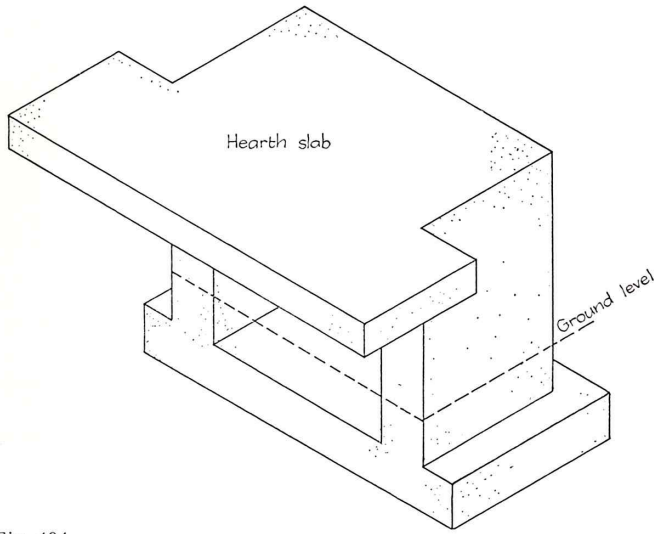


Fig. 404

Chimney foundation and hearth slab

The specifications and drawings of a job show the weight, type, design, and position of the reinforcement, which may be a simple arrangement of bars, or a complicated design in the form of a mat, cage, or skeleton, depending on the position it will occupy in a floor, wall or beam. On the other hand, welded wire fabric reinforcement of either square or rectangular mesh may be used.

Reinforcing steel bars are cut to the required lengths and bent to shape as shown on the drawings. They are then placed in position, bar by bar, lapped and securely tied or welded to form a solid framework of steel. On the other hand, the steel may be assembled as a unit and then placed in the formwork. The smaller sizes of reinforcing steel are cut with shears or hand machines and the larger sizes with power machines.

Bars, up to $1\frac{1}{4}$ in. in diameter are bent cold in simple bar-bending machines or by other means producing an even bend, but above this diameter the bars are bent at a cherry-red heat.

Concrete cover over steel

If reinforcing bars have too little cover of concrete they will rust and in the rusting process expand and eventually break up the concrete and thus weaken or spoil the appearance of the structure. The fixing and placing of reinforcing bars in their correct positions as to place and cover cannot be done too carefully.

The amount of cover for reinforcing bars is given in N.Z.S.S. 95, Part V.

Fixing

The principal points for attention when fixing steel are:
(1) That the reinforcing bars should be placed in the correct position as shown on the drawings and given the right amount of cover.
(2) That bars should be secured at places where they touch or cross other bars.
(3) That reinforcing bars should be free from grease, oil, dirt, and loose rust.

Questions on Chapter 15

(1) Sketch a vertical cross section of the formwork of a 4 ft. concrete wall 5 in. thick for a house on a level section.

(2) Describe how you would arrange the shuttering for a concrete basement wall 15 ft. high, with shutters on both sides of the wall. Illustrate your answer with sketches.

(3) (a) State the kind and grade of timber that is used for formwork.
(b) What is the most desirable moisture content for formwork?
(c) Formwork should possess certain desirable features. What are they?

(4) What two methods are used for securing plates on the top of concrete walls? Describe each method in detail.

(5) Show by a sketch how you would set out the strings for a flight of concrete steps with a rise of 2 ft. 11 in. and a going of 3 ft. 4 in.

(6) Give examples and explain the factors governing the removal of formwork from a concrete wall.

(7) Nailing strips have been omitted in a concrete wall of a house to which a number of joinery fittings are to be fixed. Describe in detail how you would secure these fittings to the wall.

(8) What is the concrete "cover" of reinforcing bars in a wall and why is such cover necessary?

(9) List the points you would note when making a final inspection of formwork before the concrete is to be placed.

(10) Fully explain why it is necessary to have reinforcing steel in concrete.

(11) What precautions would you take with steel reinforcement to ensure adequate bond between the concrete and the steel?

(12) Explain how you would set out and prepare the formwork for the foundation of a dwelling on a level section.

Calculations

(1) In measuring for a flight of stairs it is found that the distance from floor to floor is 8 ft. 9 in. If 15 risers are required, what is the rise of each step? If twice the rise plus the 'going' is equal to 23, what is the going of a step and also the total going?
Note: The number of risers in a flight of stairs exceeds by one the number of treads.

(2) A farm gate has five horizontal bars, two uprights at each end, and a diagonal brace. If the gate is 8 ft. 4 in. wide and 4 ft. 6 in. high, calculate:
(a) The number of linear feet of timber (to the nearest foot) required for the gate.
(b) The number of feet B.M. when 3 in. x 1 in. timber is used to make the gate.

(3) Find the weight of brickwork that a concrete lintel beam would support in brick-veneer work. It is assumed that the load on such a beam is equal to the weight of brickwork contained in an equilateral triangle, the base of which is equal to the length of the beam. The beam is 6 ft. long, the brick $4\frac{1}{4}$ in. thick, and the brickwork weighs 140 lb. per cubic foot.

(4) A concrete septic tank has internal dimensions of 6 ft. by 3 ft. 6in. and has an overflow pipe 4 ft. 3 in. from the bottom of the tank. Calculate the capacity of the tank:
(a) In cubic feet.
(b) In gallons (1 cu. ft. $= 6\frac{1}{4}$ gal.).

(5) A drain has a fall of 7 ft. and a horizontal run of 24 ft. What is the length of the drain and how many full-length 2 ft. pipes would be required to lay the drain?

Chapter 16

CONCRETE

Concrete is an intimate and uniform mixture of cement, water, and inert aggregates.

Cement

Portland cement

As Portland cement is an important ingredient in concrete we should know of its origin, manufacture, and composition. In 1824 Joseph Aspdin mixed together clay and limestone, thoroughly burnt the mixture and then reground it to a fine powder. This he named Portland cement because when set, it resembled the building stone quarried at Portland, England. This name still belongs to cement made all over the world to an improved formula. Portland cement is made from a mixture of calcareous material such as chalk and limestone and argillaceous material such as clay, mud, and shale mixed together in the proportions of approximately 75 per cent calcareous material and 25 per cent argillaceous material. These materials are usually ground by a "wet process" but a "dry process" is sometimes used and is often to be preferred (*Fig.* 405).

In New Zealand cement is frequently packed in multi-walled paper bags containing 93⅓ lb.* (24 to 1 ton), but 112 lb. bags (20 to 1 ton) are also available. Cement is also shipped in bulk and stored in silos for bagging as required, or distribution by tank trucks to large users of cement.

Composition of cement

Portland cement is a standardised world product with small variations in composition fixed by the standard specifications of most countries. A typical modern Portland cement contains 65 per cent lime (Ca O), 24 per cent silica ($Si O_2$), 5 per cent aluminium oxide (Al_2O_3), and small amounts of iron oxide, sulphur trioxide, and magnesium oxide.

Ordinary Portland cement

The ordinary or normal grade of Portland cement is used for general purposes and for the majority of concrete works.

Rapid-hardening Portland cement

Rapid-hardening Portland cement is made in much the same way as ordinary Portland cement except that it has an increased lime content, is ground much more finely, and is burnt at a higher temperature. These differences give the cement what is known as a high early strength. Rapid hardening cement is not a quick-setting cement, its setting times being only slightly less than ordinary cement, but the hardening process proceeds much more rapidly. At the age of two days it attains about the seven-day strength of ordinary cement, while at seven days it attains the strength of ordinary cement at twenty-eight days.

White cement

Iron imparts to cement the well known grey tint and specially selected materials have to be used in the manufacture of pure white cement.

Coloured cement

For special finishing jobs coloured cements are marketed with the pigments incorporated during the grinding process.

High-alumina cement

High-alumina cement, often known as *ciment fondu,* under which name it was sold in France where it was first made, is made from bauxite* and chalk. It has an important advantage over ordinary and rapid-hardening Portland cement in that it attains in one day a compressive strength greater than other cements attain in twenty-eight days. As there are no suitable bauxite deposits in New Zealand high-alumina cement is an imported product.

Special cement

Special cement may be used only with the consent of the local authority engineer. Such cements include those with quick setting, water repellent, or other special properties.

Storage of cement

Cement should be stored and handled at all times so that it is protected against moisture from the air, the ground, or any other source. Temporary structures for cement storage should be constructed to exclude dampness and tarpaulin covers may be used as an additional protection against moisture. Cement temporarily stored out of doors should be on a raised platform, covered with tarpaulins so arranged that they will not come in direct contact with the bags and tied to prevent disturbance by wind.

Aggregates

Aggregates are the inert particles that are bound together by the cement paste to form mortar and concrete. The whole purpose of good concrete is to make a material as closely resembling good aggregate as possible. In other words, concrete is made of pieces of aggregate

*For the purpose of calculation a 93⅓ lb. bag of cement is taken as containing 94 lb.

*Bauxite is a naturally occurring mineral containing 50 to 70 per cent of aluminium oxide (Al_2O_3), about 25 to 30 per cent of water, with varying amounts of ferric oxide, titanic oxide, and silica.

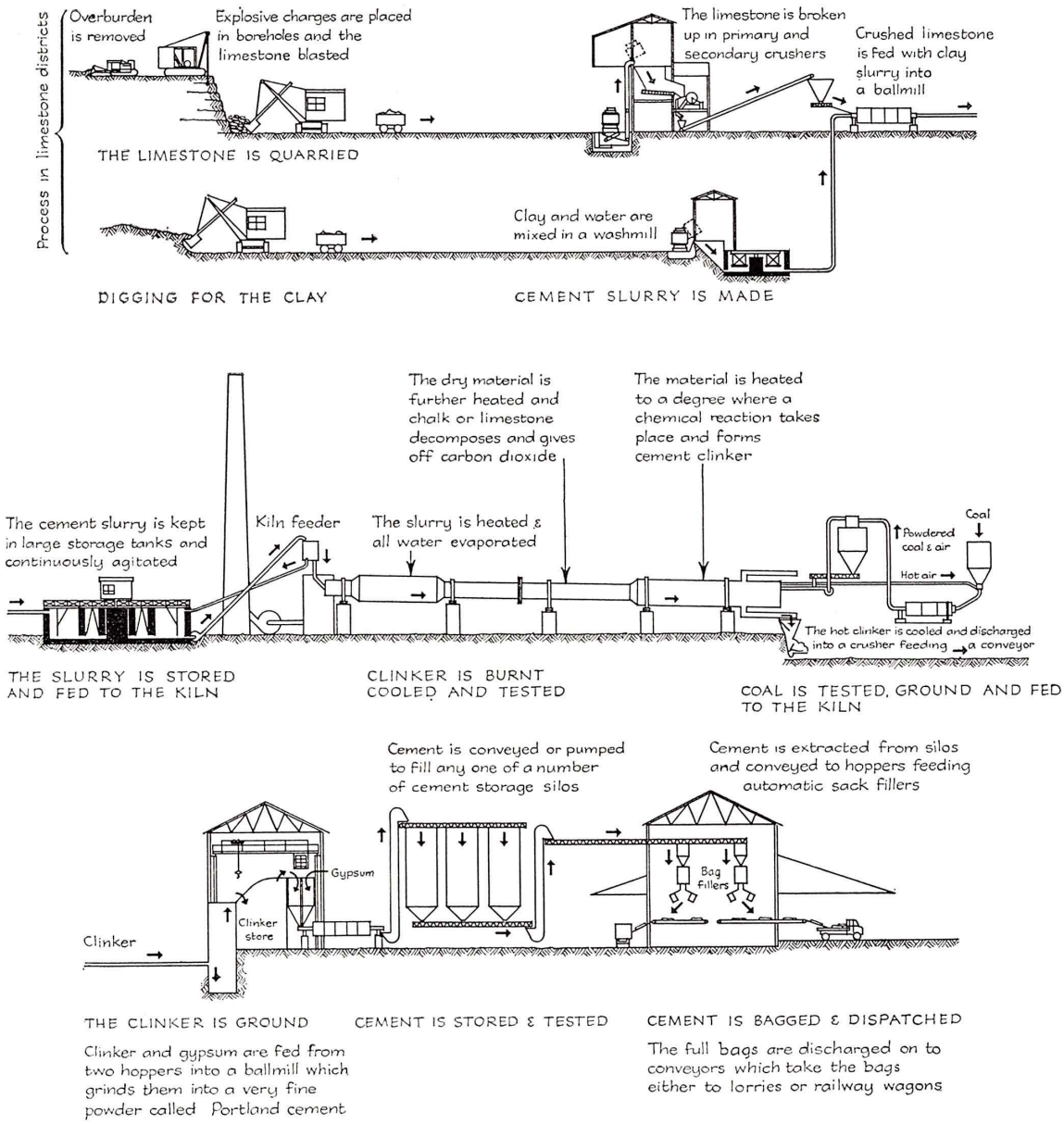

Process in limestone districts
Overburden is removed
Explosive charges are placed in boreholes and the limestone blasted
The limestone is broken up in primary and secondary crushers
Crushed limestone is fed with clay slurry into a ballmill
THE LIMESTONE IS QUARRIED
Clay and water are mixed in a washmill
DIGGING FOR THE CLAY
CEMENT SLURRY IS MADE
The dry material is further heated and chalk or limestone decomposes and gives off carbon dioxide
The material is heated to a degree where a chemical reaction takes place and forms cement clinker
The cement slurry is kept in large storage tanks and continuously agitated
Kiln feeder
The slurry is heated & all water evaporated
Coal
Powdered coal & air
Hot air
The hot clinker is cooled and discharged into a crusher feeding a conveyor
THE SLURRY IS STORED AND FED TO THE KILN
CLINKER IS BURNT COOLED AND TESTED
COAL IS TESTED, GROUND AND FED TO THE KILN
Cement is conveyed or pumped to fill any one of a number of cement storage silos
Cement is extracted from silos and conveyed to hoppers feeding automatic sack fillers
Gypsum
Clinker store
Clinker
Bag fillers
THE CLINKER IS GROUND
Clinker and gypsum are fed from two hoppers into a ballmill which grinds them into a very fine powder called Portland cement
CEMENT IS STORED & TESTED
CEMENT IS BAGGED & DISPATCHED
The full bags are discharged on to conveyors which take the bags either to lorries or railway wagons

Fig. 405

Diagram showing stages in the manufacture of cement

fitted and glued together with cement paste to form a solid mass. The quality of the concrete is entirely dependent upon the quality of the cement paste, and also upon its effectiveness in sticking the pieces of aggregate together. Such effectiveness will largely depend upon the quality of the aggregate and the proportions of the particles of different sizes in the aggregate.

Source

Aggregates are classed as natural or artificial. Aggregates of natural origin include sand and gravel from alluvial or glacial beds and crushed rock such as granite, basalt, limestone, etc. Pumice is a lightweight aggregate of natural origin. Artificial aggregates such as furnace clinker, coke breeze, broken brick, etc., are not used to any great extent in this country.

For certain special-purpose concretes, light-weight, soft, porous aggregates such as cinders, pumice, scoria, and sawdust are used. In these, strength gives place to other requirements, usually thermal insulation, sound absorption, lightness, suitability for nailing, or walking resilience.

Cleanness

Natural aggregates may include a small percentage of deleterious substances from natural sources such as clay lumps, coal and lignite, shale, alkali, mica-coated grains, and soft and flaky particles. Very fine material (stone dust) passing a 200 test sieve is also regarded as a deleterious material. Most of these materials are removed by wash screening. Organic matter may be present in aggregates in such small amounts that it cannot be detected by visual inspection. Such matter results from decaying leaves, bark, wood, and organic matter generally. The aggregates should not contain more than a certain percentage of organic impurities. (See N.Z.S.S. 1051, Tables A and C, Permissible Limits for Deleterious Substances in Aggregates. Appendix VI describes a test for organic impurities in sand for concrete.)

Strength

The qualities usually required of concrete are strength, durability, and water-tightness, for which only hard, sound aggregates, such as natural sands, gravels, or crushed stone, are suitable. Concrete made from hard, sound aggregate would have a high crushing strength, but that made from soft aggregate (certain kinds of limestone, etc.) would naturally have a lower crushing strength.

Choice of aggregates

The type of aggregate used is generally governed by the local sources of supply. Concrete of reasonable quality may be made with almost any natural stone, rock, or gravel, though the suitability of various kinds of aggregate may differ considerably according to the kind of concrete required. For example, certain limestones are soft and particles are laminated, elongated, or flat and consequently unsuitable for concrete exposed to severe abrasion. Generally the quality of an aggregate depends less on the type of rock than on the nature of the particles, their shape, size, and grading. Many aggregates are known by experience to be of good quality and may be used without hesitation.

Particle shape of aggregates

Natural aggregates from river or beach sources vary in shape from almost perfect spheres to thin elliptical discs. Nearly spherical aggregate particles make concrete that is more readily compacted than concrete with flat particles. One can understand that it is easier to compact a concrete made of marbles than one made with assorted coins. For this reason flat or flaky aggregates should at all costs be avoided as they make weak concrete. Rounded aggregates are frequently used with crushed oversizes of spherical shape, which have been carefully screened.

Aggregate from crushed rock has an angular shape. Concrete made of angular aggregates is not so easily worked into place as concrete of rounded aggregate but this difficulty is overcome by the proper grading of the crushed stone into fine and coarse aggregate. The rounded nature of gravels permits them to be used at a lower water-cement ratio than for angular aggregates but at an equal water-cement ratio the interlocking properties of angular aggregates makes a concrete which tends to have a higher compressive and flexural strength than concrete of rounded aggregates. Good concrete may be made with either rounded or angular aggregates, the use of which will be determined by requirements as to strength, workability, and economy.

Grading of aggregates

The term "grading" is used to describe the proportions of different sizes of particles in an aggregate. The grading of an aggregate affects the uniformity, quality, and strength of concrete as well as the workability, which is the ease or difficulty experienced during the placing and compacting of the concrete. A correctly graded aggregate makes concrete with the desirable qualities of uniformity, density, and strength, with a higher crushing strength than a concrete made of ungraded or poorly graded aggregates.

Maximum size of aggregate

Reinforced concrete specifications limit the maximum size of aggregate to $\frac{3}{4}$ of the cover or, $\frac{1}{4}$ in. less than the minimum clear spacing between reinforcing bars. Generally, the larger the maximum size of aggregate conforming to the above conditions, the better the concrete, because at any cement content the concrete will not only have a higher compressive strength but also will shrink less.

Graded aggregates

An aggregate should contain all sizes of particles from the largest to the smallest in the proportions that will give the desired workability and at the same time maximum strength and watertightness. It has been found in practice that this can best be obtained by dividing the aggregate into two particle sizes of coarse and fine aggregate.

Fine aggregate

Fine aggregate is sand ranging in size from particles passing a $\frac{3}{8}$ in. test sieve to particles 0–10 per cent of which should pass a No. 100 test sieve. Material of so fine a nature that it will pass a No. 200 (aperture size, 0·0049 in.) test sieve is regarded as a deleterious substance. (N.Z.S.S. 1051.)

Coarse aggregate

Depending upon the job for which it is intended coarse aggregate may range in size from $1\frac{1}{2}$ in. to $\frac{3}{16}$ in., 1 in. to $\frac{3}{16}$ in., $\frac{3}{4}$ in. to $\frac{3}{16}$ in., $\frac{1}{2}$ in. to $\frac{3}{16}$ in., and $1\frac{1}{2}$ in. to $\frac{3}{4}$ in. (N.Z.S.S. 1051.)

All-in aggregate

Aggregates not separated into separate grades are called by a variety of names such as "builder's mix", "all in mix", and "mixed shingle and sand", etc. Such a mixture

is usually loaded into a truck direct from the gravel pit and even if attempts are made to add either coarse or fine material the concrete made from such aggregate cannot produce concrete of uniform or good quality. Such a mixture of aggregate will at one time contain too much sand and at other times too much coarse material.

An oversanded aggregate requires cement above normal requirements to produce concrete of proper strength.

On the other hand concrete made from aggregate deficient in fine materials will be stony and harsh, difficult to place and compact, and the set concrete will be "honeycombed" and have a high proportion of air spaces or voids. Besides being of low strength and durability such concrete is so porous that insufficient protection is provided for the reinforcing steel.

Handling aggregate

Care should be taken when handling aggregate to see that the larger pieces of aggregate do not become separated from the finer particles. This is known as segregation, and may occur during any of the processes of handling the aggregate from its manufacture to its eventual loading into the mixer. A sample of aggregate taken from one part of a stock pile may vary greatly in aggregate sizes from that taken from another part of the pile. This difficulty is obviated to a large extent when aggregates are delivered to the job in separate truckloads of fine or coarse aggregate and the aggregates proportioned as they are loaded into the mixer.

Water for concrete

Water from the local authorities' water supply systems is acceptable for mixing cement grout, mortar, and concrete. When such water is not available, normal, fresh, clean water may be used, but where such water contains any sugar or excess of acid, alkali, or salt, the engineer may refuse to permit the use of such water for the making of concrete. See N.Z.S.S. 95, Part V.

Water content

Water combines with the cement and makes a paste which coats the particles of aggregate. It will be seen that it is not the proportion of water relative to the whole of the aggregate that is important but the proportion of water relative to the cement. The quantity of water used determines the strength of cement paste and consequently that of the concrete produced.

When a cement paste is made with an excessive quantity of water the strength of the concrete is lowered, and, conversely, within limits, the lower the water content, or water-cement ratio, the higher will be the strength of the concrete produced.

Water-cement ratio

The proportion of water to cement is known as the water-cement ratio.

Example: What is the water-cement ratio of a concrete mix when 5·3 gallons of water are used with one bag (94 lb.) of cement?

1 gallon of water weighs 10 lb.

Therefore 5·3 gallons weigh 53 lb.

$$\text{Water-cement ratio} = \frac{\text{weight of water}}{\text{weight of cement}}$$

$$= \frac{53}{94} = 0{\cdot}56$$

The lowest possible water-cement ratio is about 0·35 by weight and good results are obtained with water-cement ratios of 0·5 and 0·6 by weight. When above 0·8 poor results must be expected.

Water-cement ratio may also be expressed in gallons per bag of cement. *Fig.* 406 shows the general relationship between water-cement ratio and the compressive strength of concrete for New Zealand cements and aggregates.

Water content and workability

The amount of water required to give workability to a concrete mix depends to a large extent on the type and grading of the aggregate used. A concrete mixture deficient in fine material, for example, needs more water to make it workable; also one with an excess of fine materials requires more water to wet the extra surface area of the aggregate. Rounded aggregates, on the other hand, require less water than angular aggregates to give the same workability. When more water is used with a particular kind of aggregate more cement should be added to prevent the water-cement ratio being too high and so weakening the cement paste. This shows that it is good practice to use a properly graded aggregate that will be workable with a minimum quantity of water.

Permeability and density

As concrete ages and dries out, water uncombined chemically with the cement is evaporated and air spaces or voids are left. If these voids are few and small they may not connect with one another but if they are large they are almost certain to provide continuous paths for water seepage. For this reason the amount of water in concrete should be kept as low as possible to ensure that the air spaces are reduced to a minimum and so do not join into continuous paths throughout the mass of the concrete.

Methods of measuring materials

As jobs are of all sizes the methods of measuring the materials, and the plant used, must vary to suit the job. The most accurate method of measuring materials for concrete is to weigh them, but they may also be measured by volume. N.Z.S.S. 95 Part V requires that cement for all graded concrete be measured by weight but allows aggregates to be measured either by weight or by volume. Water also may be measured by weight or by volume.

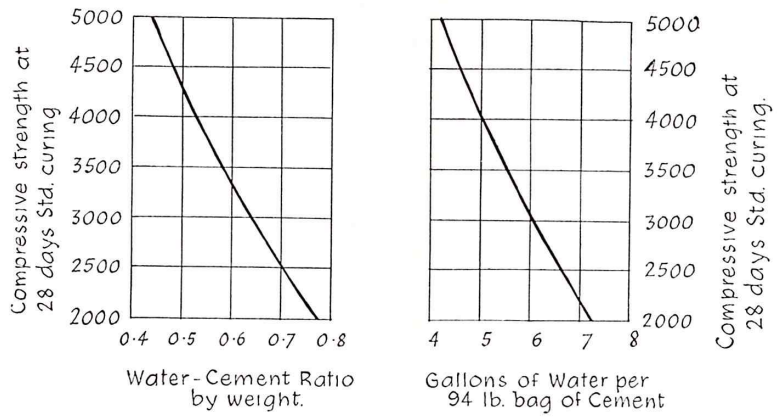


Fig. 406

Probable compressive strengths for various water-cement ratios

Cement and fine aggregate should preferably be measured by weight because of the bulking or increase in volume of the same weight of these materials.

Bulking of cement and aggregates

A cubic foot of cement may vary in weight from 60 to 100 lb., depending upon the fineness of the cement and its degree of compaction. For this reason it is necessary to measure cement by weight or by the whole bag. Fractions of a bag of cement should always be weighed.

Fine aggregate

A given volume of fine aggregate (sand) occupies the same space when it is perfectly dry as when saturated with water but at intermediate moisture contents the sand has an increased volume. This peculiarity, known as "bulking", may be demonstrated by the following experiment:

From the sand stock pile fill a container with damp sand, and then add water until the surface of the sand is flooded. It will be noted that the level of the sand has been lowered with the addition of water. Dry the sand in an oven until all the water has been evaporated, and it will be found that the volume of the dry sand is identical with that of the inundated sand. If the original depth of the sand in the container was 10 in., and 8 in. the depth of the inundated (or dry) sand, the 2 in. drop in the level of the sand is a measure of the bulking that occurs, which is 25 per cent. The degree of bulking that occurs in sand varies with the type of sand (the finer the sand the more it will bulk) and with its varying moisture content. Five or six per cent of moisture in sand produces a maximum amount of bulking. As the moisture content of sand varies between 1 and 12 per cent, the bulking of the sand should be regularly determined. This may be done by filling a container of known capacity (A) with damp sand, and then adding water and rodding the sand to expel the air until the water just floods the surface. The volume of the inundated sand is B, and the percentage of bulking is $\frac{(A - B) \times 100}{B}$ per cent.

When proportioning the damp sand an *extra* quantity equal to the percentage bulking must be added.

Coarse aggregate

The bulking effect of moisture on coarse aggregate is negligible so that quantities may be satisfactorily measured by volume.

Batching of materials

Batching is the process of measuring the materials in their specified proportions by weight or by volume.

Batching by weight

Batching plants for the weight batching of materials for concrete are being used to an increased extent and specifications frequently demand, even on jobs that are not at all large, that weight-batching methods be employed.

On the average building job the cement can usually be measured by the whole bag and the aggregate weighed on ordinary platform scales capable of carrying a wheelbarrow. If the scales are placed conveniently near to the stock piles of aggregate and the barrow is placed on the scales, the materials may be shovelled directly into it and weighed. Water may be measured in a calibrated tank or bucket, or weighed.

Batching by volume

Although the aggregates may be batched by volume, the cement, unless whole bags are used, should be weighed in a bucket suspended from a 100 lb. spring balance. A wheelbarrow may be used as a measure for aggregate, provided the volume that it will hold has been determined accurately, e.g., by filling it by means of a box of known volume. It is important that the level of each load be struck off with a screed so that loads will not vary.

Another method of measuring aggregate by volume is to use a bucket of known capacity (in cubic feet) or a batch-box in the shape of a frame with handles. Such a frame is made of proportions to suit a particular mixing programme, e.g., if a quarter-yard mix is being used, a whole bag of cement may be mixed with each batch of materials. For a 6 : 1 mix, 6 cu. ft. of aggregate is required and the batch-box is constructed to contain that quantity (or a simple fraction of it) when it is filled (level with the top of the sides).

Many concrete mixers are fitted with a hopper, the capacity of which may be determined so that aggregate may be shovelled directly into the hopper and there measured. Batching by shovelling aggregate directly into the mixer cannot be recommended; it must lead to a variable product.

It is obviously necessary to be even more particular when measuring quantities of cement since small variations can have a profound effect upon the quality of the concrete. Unless whole bags are used, the cement must be weighed, so that an exact volume is obtained.

It should be remembered that the 94 lb. bag of cement contains 1 cu. ft. and that the 112 lb. bag approximately $1\frac{1}{5}$ cu. ft. (This figure of $1\frac{1}{5}$ is obtained by dividing 112 by 94.)

Examples

(1) A 6 : 1 mix is required and it has been determined that a screeded barrow load of aggregate is $1\frac{1}{4}$ cu. ft. Using a small mixer batch two barrow loads of aggregate ($2\frac{1}{2}$ cu. ft.) with $2\frac{1}{2} \times \frac{1}{6}$ i.e., $\frac{5}{12}$ cu. ft. of cement.
Since 1 cu. ft. of cement weighs 94 lb.,

$\frac{5}{12}$ cu. ft. of cement weighs $\frac{94}{1} \times \frac{5}{12}$, i.e., $39\frac{1}{6}$ lb.

Therefore, $39\frac{1}{6}$ lb. of cement is weighed out for each batch.

(2) A 4 : 2 : 1 mix is required; a bucket of capacity $\frac{1}{2}$ cu. ft. is used as a measure.
Take 4 bucketfuls of coarse aggregate (2 cu. ft.), 2 bucketfuls of fine aggregate (1 cu. ft.), and $\frac{1}{2}$ cu. ft. of cement.
Therefore, the weight of cement to be weighed out is $\frac{1}{2}$ of $\frac{94}{1}$, i.e., 47 lb. of cement.

Estimating concrete materials

Table 13 gives the quantities of materials necessary to make 1 cu. yd. of concrete suitable for general use.

Table 13

Quantities for 1 cu. yd. of concrete

Mix	Cement lb.	Total water lb.	Fine aggregate (5 per cent moisture) cubic feet	Coarse aggregate cubic feet
1	564 (6 bags)	320 (32 gal.)	$16\frac{1}{2}$	18
2	564 (6 bags)	324 (32·4 gal.)	12	24

Notes:

(1) Mix 1 comprises aggregates graded strictly in accordance with N.Z.S.S. 1051.

(2) Mix 2 comprises aggregates of grades commonly used, without excessive fines in the coarse aggregate.

The total space to be occupied by the concrete is calculated in cubic yards. The amount of aggregate to be ordered will be more than this, however, as part of the fine aggregate simply fills in the voids in the coarse. The amount of material to be ordered is obtained by multiplying each ingredient in the mix chosen by the number of cubic yards of concrete required.

Example: $2\frac{1}{4}$ cubic yd. of concrete are required for a particular job. Estimate the quantities of the materials required if mix 2 is to be used.

Cement	$564 \times 2\frac{1}{4} = 1{,}269$ lb.	$= 13\frac{1}{2}$ bags (or 14 to order)
Water	$324 \times 2\frac{1}{4} = 729$ lb.	= 73 gal.
Fine aggregate	$12 \times 2\frac{1}{4} = 27$ cu. ft.	= 1 cu. yd.
Coarse aggregate	$24 \times 2\frac{1}{4} = 54$ cu. ft.	= 2 cu. yd.

Mixing of materials

If a batch of concrete when mixed to the above proportions has poor workability (dry and does not flow easily) reduce the amount of aggregate; if it flows very easily, increase the aggregate; if harsh, increase the fine aggregate only. Never alter the amount of water to increase or decrease workability because, as stated previously, an increase in the water content will seriously lower the strength of the concrete.

The ingredients of concrete are mixed until all the particles of aggregate are thoroughly coated with cement paste and the mix is of an even colour.

Hand mixing

Hand mixing of concrete is considered to be an inefficient practice and in any case is rarely done these days. When concrete is mixed by hand 10 per cent extra cement above normal requirements should be added. The materials are placed on an even, watertight surface with the cement on the top of the heap, and after all the ingredients have been thoroughly mixed in a dry condition, water is added and then the whole mass is again thoroughly turned over until the concrete is of a uniform colour.

Machine mixing

Machine mixing of concrete is much more efficient and cheaper than hand mixing methods.

Ready-mixed concrete

In the larger towns ready-mixed concrete is supplied to builders from central mixing plants, thus saving space

and labour of handling and mixing the materials on the job. This service provides the builder with concrete of a desired standard for the work in hand.

Ready-mixed concrete may be mixed and delivered by one of the following two methods:

(1) The concrete mixed at a central mixing plant and transported to the job in a revolving drum equipped with an agitator.

(2) The materials batched at a central plant and mixed in a truck-mixer during transit to the job (transit-mixed concrete).

Ready-mixed concrete is discharged from the truck into a hopper from which it is transported by barrows to where it is required.

Concrete mixers: batch type

Concrete mixers used on building jobs vary in capacity from 2 to 10 cu. ft. and may be of the tilting or non-tilting type. (N.Z.S.S. 1052, Batch-type Concrete Mixers.)

On small building jobs the tilting type of mixer with a capacity from 2 to $3\frac{1}{2}$ cu. ft. is most popular, although tilting types of mixer up to 10 cu. ft. are available. Such mixers are mounted so that they are turned upwards while in use and downwards to discharge their contents. The non-tilting type of concrete mixer ranges in capacity from 5 to 10 cu. ft. and consists of a drum with an opening on either side. Mixers of this kind and size often have power-operated lifting arrangements that raise and discharge a hopper full of unmixed materials into the mixer. The mixed concrete is discharged into barrows or a movable chute.

Every concrete mixer should be equipped with a water-measuring device, either automatic or otherwise, so that any desired quantity of water may be readily measured.

Mixing time

When a concrete mixer has a capacity of 1 cu. yd. or less, the materials should be mixed for one and a half minutes. The drum should rotate at a peripheral speed of approximately 200 ft. per minute at a point on the widest section of the drum, or at a speed of 12 r.p.m., whichever is the slower. (See N.Z.S.S. 95, Part V.)

Control tests

However accurately the materials for concrete may have been batched it is always advisable to make regular slump and compression tests, to determine whether the materials have been correctly batched.

Slump test

The slump test gives an indication of the workability of concrete and its suitability for conveying, placing, and compacting in certain types of work. The test will vary over a wide range depending upon the wetness of the mix, the quantity of the cement used, the size of aggregate, the ratio between the fine and coarse aggregate, the shape of the aggregate particles, and the mixing time. The value of the slump test is that it can indicate quickly if any of the above factors in a definite mix are altered. For example, the slump test is used to compare wetness of successive batches of concrete containing similar materials and proportions of materials. A slump test is carried out by filling a metal cone with three layers of wet concrete, each layer being rodded with a metal rod. When the cone is removed, the unsupported mass of concrete may remain firm, drop a little, or collapse according to the wetness of the concrete. The difference in height of the cone and that of the slumped mass of concrete is known as the "slump" of the concrete (N.Z.S.S. 192, Methods for the Testing of Concrete).

Compression tests

Compression strength is a measure of the quality of concrete and is the average strength of at least three 12 in. x 6 in. diameter concrete cylinders crushed to failure. Such a test is made by taking representative samples from batches of concrete and placing them in moulds. After a twenty-eight-day curing period the compressive strength of the concrete specimens is determined by crushing in a test machine (N.Z.S.S. 192, Methods for the Testing of Concrete).

Placing of concrete

The mixed concrete should be handled as speedily as possible and the whole process of conveying, placing, consolidating, and finishing should be carried out within a period of thirty minutes. When concrete is dumped or dropped care should be taken to prevent the coarse aggregate from being separated from the finer materials. Concrete should be deposited close to its final location and not allowed to flow laterally more than 2 or 3 ft. The top layer should be kept as level as possible. No more concrete should be deposited in one place than can be conveniently vibrated and effectively consolidated around the steel reinforcement and into all parts of the formwork, thus ensuring that the steel is thoroughly coated with cement paste and that there are no voids or cavities in the concrete mass.

Concreting should, if possible, be carried out continuously until the job is completed, or to construction joints arranged either horizontally or vertically. Construction joints in beams, slabs, and columns are formed at right angles to their length and are located at positions of low shear stress.

The depth of the concrete placed in each layer or "lift" should be not more than 2 or 3 ft., or in such lifts as can be properly consolidated.

As each lift is placed it must be consolidated and worked well into the upper surface of the layer below.

When a delay of more than an hour occurs in the placing of the concrete, the surface of a layer must be regarded as a "cold joint" and allowed to harden for at least three hours. Before succeeding layers of concrete are placed this surface should be broomed over with a grout of cement and water having the proportions of cement and water similar to those of the concrete being placed. Before fresh concrete is placed against concrete that has already hardened the surface of the hardened concrete should be roughened, the loose material and foreign matter cleared away, and the surface covered with freshly made mortar composed of one part of cement to two parts of sand to a depth of $\frac{1}{2}$ in.; or freshly made cement grout may be broomed into the surface.

Tamping and vibration of concrete

In reinforced concrete work it is most important that the concrete be compacted and worked around the reinforcement and into all parts of the formwork without voids or cavities, so that the concrete will be waterproof and also take the full stress for which it is designed. The compacting of concrete is done by either hand-tamping tools or by mechanical vibration.

Hand tamping

Hand tamping is the compaction of concrete with various hand tools such as spades and tampers. A simple tamping tool for a small job is made of a steel rod with a piece of flat steel welded to one end. Hand-tamping methods are considered unsatisfactory because they rely too much on the human element.

Mechanical vibration

Mechanical vibrators are of four types as follows:
(1) Immersion vibrator: This kind of vibrator is immersed into the concrete being placed and is used in a variety of situations.
(2) Shutter vibrator. Vibrators of this kind are fixed to the formwork and have value for vibrating concrete in thin wall sections where immersion vibrators cannot be used.
(3) Surface vibrators: Surface vibrators are used on screeds for consolidating the concrete of floors.
(4) Vibrator tables: These vibrators are attached to tables on which concrete is being cast for beams, posts, etc. and pre-cast work generally. Vibrators generally may be operated by either electric or petrol-driven motors.

Methods of vibration

Vibration should only be continued a sufficient length of time for the concrete to be thoroughly consolidated, as shown by the levelled appearance on the surface of the concrete. The vibrator is immersed at intervals of 18 in. to 30 in. and the period of immersion is usually from five to fifteen seconds depending on the stiffness of the concrete. When using an immersion vibrator it should be immersed to the depth of the concrete being placed and withdrawn slowly and operated continuously so that a hole is not left in the concrete. Vibration for too long will cause the coarse aggregate to settle to the bottom and the finer materials to rise to the top. One advantage of using vibrators is that the amount of water in mixing the concrete may be reduced and so stiff mixtures, unworkable by hand, may be placed.

Concreting in cold weather

All cement generates heat during setting, and if this heat can be conserved in the concrete a satisfactory means of protection against frost is presented. To conserve this naturally developed heat it is necessary to insulate the concrete, and for this purpose the usual timber shuttering is quite effective; but where there is no shuttering it is not sufficient merely to cover the exposed surface of the concrete with sacks. It is important that there should be no circulation of air over an exposed, newly laid concrete surface during frost, and suitable means of protection are to cover with close boarding, as used for shuttering, or with tarpaulins, so placed as to exclude draughts but to leave a few inches between the concrete and the tarpaulin. For successful concreting in cold weather it is essential that the sand and aggregate should not be mixed in a frozen condition, and if the water used for mixing can be heated to about 80°*F.*, additional protection against frost is provided. As soon as concrete has hardened, there is, of course, no further risk of damage by frost.

Curing

The protection of newly laid concrete from heat and drying winds is most important because cement requires warm moist conditions for the first week or two in order to attain its proper strength. The controlled curing period prevents the formation of surface cracks caused by the rapid loss of water and consequent contraction.

Removal of formwork *(see also page 222)*

Formwork should not be removed until a certain period of time has elapsed after placing the concrete and this depends upon the kind of cement used (rapid-hardening or normal Portland cement) and also on the situation of the formwork, e.g., beam sides or walls, etc. A guide for the removal of formwork is given in N.Z.S.S. 95, Part V.

Formwork should be removed without shock or vibration and in such a manner that the concrete may gradually take the stresses due to its own weight.

Questions on Chapter 16

(1) Describe the origin of Portland cement and its manufacture from the raw materials to the finished product.

(2) (a) Name the varieties of Portland cement that are available.
(b) What is the difference in the manufacture of ordinary and rapid-hardening Portland cement?

(3) (a) What extra precautions should be taken to prevent the deterioration of a ton of cement stored in a shed with a concrete floor?
(b) Briefly state the reasons for such precautions.

(4) (a) Describe the several kinds of aggregate that may be used for making concrete.
(b) How is aggregate graded for ordinary concrete?

(5) To produce concrete of a certain strength what general factors should be considered so that a minimum amount of cement is used?

(6) (a) What water-cement ratio should be adopted for making good concrete?
(b) Assuming that the aggregate carries no free water, convert the answer of question (a) into gallons of water for:
(i) 1 cubic ft. (94 lb.) of cement.
(ii) $124\frac{1}{2}$ lb. of cement.

(7) Calculate the quantities of cement, sand, and metal chips required to produce 55 cu. ft. of concrete using a nominal mix of 4 : 2 : 1 and 564 lb. of cement to every cubic yard of set concrete. Answer to be given in whole numbers of bags of cement and cubic feet of other materials.

(8) (a) Describe how you would recommend concrete materials to be batched, mixed, and placed in position.
(b) Describe how a surface of set concrete is prepared for fresh concrete to be placed.
(c) What precautions would be taken when the last batch of concrete for the day is in process of being placed and the formwork has not been filled?

(9) What are the main points for consideration for the curing of concrete in hot weather?

(10) What is meant by the slump test? Describe and sketch the apparatus used for the test.

(11) What is meant by water content, how is it controlled, and what is its effect on the strength of concrete?

Calculations

(1) Concrete is made in the proportion of 4 parts aggregate, 2 parts sand, and 1 part cement. If $29\frac{1}{2}$ cu. ft. of mixed materials are required to make 1 cu. yd. of concrete, what quantity in cubic feet of each material will be needed?

(2) What is the weight of cement required to be mixed with $2\frac{3}{4}$ cu. ft. of aggregate in a 6 : 1 concrete mix? (1 cu. ft. of cement weighs 94 lb.)

(3) Calculate the weight of cement for 10* cu. ft. of aggregate for concrete of 4 : 2 : 1 mix. (1 cu. ft. of cement weighs 94 lb.)

(4) The sand required to fill the voids in 30 cu. yd. of broken stone aggregate was found to be $12\frac{1}{2}$ cu. yd. How much sand would be required to fill the voids in 220 cu. yd. of similar aggregate?

(5) The gear ratio on a concrete mixer is stated to be 4 to 1. If the gear wheel on the electric motor shaft has 16 teeth, how many teeth will the other wheel have?

INDEX

Numbers in bold-face indicate pages bearing illustrations.

Access doors 169, **170,** 198
Air seasoning **55, 56**
Aggregates 229–232
Aggregates, bulking 233
Aluminium corrugated roofing sheets 139
Angle box 155, **194**
Angle stop 155, 194
Anobium magnum **59**
Architraves 199–**201**
Asphalt, mastic 140
Attendance on other trades 209–211

Backing angle, definition **115**
„ „ hip, **118, 122, 131, 132, 135,** 144
Balloon-frame construction 99, **100**
„ „ „ , semi- 99, **101**
Barge board **193**
Batching of concrete materials 233, 234
Bath framing 199, **201**
Bathroom cabinet **197**
Bell-cast finish **156**
Birdsmouth cut **128**
Bituminous felt roof coverings 140
Blue prints 42
Board measure (ft. B.M.), calculation of 51
Boxing (see concrete formwork)
Bracing of joists **97**
Bracing of walls and partitions 104, **105, 106, 109**
Brickwork, fixing joinery to **184,** 185
Brick veneer 158, **159–162**
Builders' level 77–**79**
Building permit 40, 41, **44**
Building timbers, utilisation 69–73
Built-in fitments 196, **197**–200

Ceiling runners, **108, 109**
Cement 229, **230**
Chimney breast 198, 199, **200, 201**
Chimney foundations 225, **227**
Coach bolts **36**
Coat cupboard 197
Collar roof **111**
Collar tie **111,** 114, **146**
Corrugated fasteners 34
„ iron 138
Couple-close roof **111**
Cover boards **193**
Concrete 229–236
„ aggregates 229–232
„ batching 233, 234
„ cement 229, **230**
„ curing 236
„ fixing joinery to **184,** 185, 221
„ formwork 218–227
„ „ bolting 220, 221
„ „ bracing **218, 219,** 220
„ „ construction **218,** 220
„ „ erection 220, 222
„ „ fixing joinery in walls 221
„ „ foundations 222, 225
„ „ „ chimney and hearth slabs 225, **227**
„ „ „ laundry slabs 225
„ „ ground plate **218,** 219
„ „ holding-down devices **221**
„ „ inspection 221, 222
„ „ oiling of shutters and sheathing 221
„ „ piles 222, **223**
„ „ purpose of 218
„ „ removal 222, 236
„ „ sheathing 219
„ „ shutters **220,** 222

Concrete formwork spreaders 220, 221
„ „ steps 222, **224, 225**
„ „ stud and sheathing method **218–220,** 222
„ „ timber 218
„ „ tying walls **220**
„ „ waling **218,** 220
„ frost damage 236
„ measuring materials 232–234
„ mixing 234, 235
„ permeability and density 232
„ placing 235, 236
„ reinforced-concrete floors 87, **88**
„ reinforced-concrete walls 83, **84–87**
„ tests 235
„ water cement ratio 232
„ water for 232
„ workability 232, 235
Creosote 66
Creosote preservation processes 68
Cupboard locks 205

Damp-proof course **92,** 93
Degrade in seasoning 56, 57, 58
Detail drawings 39, **40**
Design of dwellings 41
Doors 177–184
„ access 169, 170, 198
„ facings **181, 182**
„ fitting and hanging 182–185
„ fittings 203, **204,** 205
„ frames **179–182**
„ hanging **182–185**
„ hinges 183–185
„ jambs **179–182**
„ locks 203, **204,** 205
„ size 178, 179
„ timber for 71
„ types **178, 179**
„ weathering devices 180, **181, 182**
Drainage plan 39
Drawer pulls 205
Drawings detail 39, **40**
„ preparation of 42
„ reproduction of 42
Dry rot 65
Dwangs **107**
Dwarf walls **81,** 91

Eaves **191, 192**
Electric-power connections 31, 32
„ „ , earthing of appliances, isolating transformers and monitored earth-circuit breakers 32
Elevations 38, **39**
Excavations, timbering for 216
Exterior trim 191–196
„ „ , timber for 70
„ wall coverings 150–164

Fascia boards **192**
Fastening materials 33–36
Fibre saturation point 52
Fibrous plaster sheets 187
Finishing trim 191–207
Flashing 154, **157, 176, 177**

Flat roof 111, 112
Flat-sawn timber 49, **50**
Food safe 198, **200**
Foot board measure (ft. B.M.) 51, 52
Formwork for concrete 218–227
Framing timber 69, 70
„ walls **99–109**
Fungal infection 65, 66
„ prevention 65, 66
Floor framing 90–98
„ „ ground floor supports **90–96**
„ „ joists 91, **92, 94–98**
„ „ „ method of setting out **94, 95**
„ „ sleeper plates **90, 93,** 94
„ „ stringers **90**
„ „ timber 69, 70
„ „ wall plates **91,** 93, 94
Flooring 166–170
„ calculations of quantities 170
„ cramping 167, **168–170**
„ exposed 169, 170
„ heading joints 166, **167**
„ laying 167
„ nailing 166, **167,** 168, 169, **170**
„ sanding 169
„ timber 70, 71
„ types **166**
Floors concrete 87, **88**
Foundations 75–88
„ blocks **81–83**
„ brick-veneer **87**
„ dwarf walls **81,** 91
„ footings **81**
„ pile **81–83**
„ plan 38–39
„ profiles 76, **77, 78**
„ reinforced concrete 83, **84–88**
„ reinforcing steel 84
„ setting out 75, **76–79**–81
„ stepping 84, **86**
„ timber-frame buildings 81–88
„ ventilation of 85, **86**

Gable roof 111, **112**
„ „ wall finish for 192, **193,** 194
Galvanised corrugated iron 138
Grading classification of building timbers 52
Grinding and sharpening cutting tools 27, **28, 29,** 30
Ground-floor plan **38,** 39
Ground floor supports 90

Hand dressing and finishing 196
Hardware 33–36
Hardwoods **46–49,** 72, 73
Heading joints 166, **167**
Hearth slab foundations 225, **227**
Herringbone struts **97, 98**
Hip rafter (see rafters)
Hip roof 111, **112**
Hip and valley roof 111, **112**
Hinges **183, 184,** 185, 207
Holding down devices, **221**
Honing **18,** 28, **29**–30
Hot-water cupboard **198**
House borer, common **58, 59**

Imported building timbers 73
Insects attacking timber 58–64
„ control 61, 63, **64**
Interior finish 196–207
„ „ , timbers for **71**
„ wall coverings 187–189
Iron, corrugated 138

Jack rafters (see rafters)
Jack studs 103, **105**
Joinery fixing 172–185
Joists ceiling 107, **108, 109**
„ floor 91, **92–97**

Kiln seasoning 56, **57**
Kitchen cupboards **198–200**
„ joinery timber 71
„ sink bench 197, **198**
Knots **216–217**

Lean-to roof 111, **112**
Level, builders 77–**79**
Linen cupboard 197
Lintels 104, **105**
Locality plan **40**
Locks 203–205
Louvres **173**

Mastic asphalt 140
Mineral fibre cement sheets **157, 158**
„ „ „ „ corrugated (see roof coverings)
„ „ „ mouldings 158, **159**
„ „ „ sidings 156, **157**
Mitred corners, weatherboards **155**
Moisture content of timber 52–54
„ , determination of 52
Mortise lock, fitting of 203, **204**
Movement of wood 52, **53**

Nails 33, **34**
„ boring for 34
„ holding power 34
„ mineral fibre cement 158
Native trees **46, 72**

Overhang common rafter (see rafters)

Panel pins 33, 34
Partitions **92,** 102, 107
Pelmets 202
Permit, building 40, 41, **44**
Pile foundations **81–83**
Pin-hole borer 60, **61**
Pitch of roof 112, 113, **114**
Plans and permits 38–44
Plaster-core wallboards 187, 188
Plates bottom **99–102**
„ sleeper **90,** 94
„ top **99–102**
„ wall **91, 93**
Platform construction 99, **100**
Porch finishes 195, **196**
Powder-post beetles **59,** 60
Power tools **30, 31–33**
Preparation of drawings 42
Purlins 114, 148
„ under 145, **146**

Quantities—flooring 170
„ weatherboards 170
Quarter-sawn timber **50, 51**

Rafters 114–138, 140–148
„ common, length and cuts, calculation methods 148
„ „ „ „ „ , geometrical „ **116, 121,** 123, **124**
„ „ „ „ „ , practical „ 141, 142, **143**
„ „ „ „ „ , steel square „ **126–128, 135, 136,** 138
„ „ shortening **116, 128,** 143, **144**
„ definition 114
„ hip, length and cuts, calculation methods 148
„ „ „ „ „ , geometrical „ 116–**118, 121, 122, 123, 124**
„ „ „ „ „ , practical „ **143–145**
„ „ „ „ „ , steel square „ **128–132,** 135, 136–138
„ „ , shortening **117,** 118, **130,** 143, **144, 145**
„ jack, length and cuts, geometrical methods **118, 119,** 122, **123, 124**
„ „ „ „ „ , practical „ 141, 143, **144**
„ „ „ „ „ , steel square „ 131, **132,** 133–**135, 137,** 138
„ „ , shortening **119,** 133, 143, **144**
„ valley, length and cuts, calculation methods 148
„ „ „ „ „ , geometrical „ **120, 122,** 123, **124**
„ „ „ „ „ , practical „ 146, **147**
„ „ „ „ „ , steel square „ 133, **134, 135,** 136, 138
„ „ , shortening 120, **134**
„ valley jack, length and cuts, geometrical methods 120
„ „ „ „ „ „ , steel square methods 133, **134**
„ „ „ , shortening **120**
Ribbon boards 96, **97, 100**
Roof 111–148
„ classification of **111, 112, 113**
„ collar **111**
„ collar tie **111,** 114, **146**
„ couple close **111**
„ covering materials 138–140
„ flat 111, **112**
„ framing square 124, **125**
„ gable 111, **112**
„ hip 111, **112**
„ hip and valley 111, **112**
„ inclination 112, 113
„ lean to 111, **112**
„ members 113, **114**
„ pitch 112, 113, **114**
„ plans **39,** 115, **125, 141**
„ practical work 140, **141–147,** 148
„ purlins 114, 145, **146,** 148
„ rafters (see rafters)
„ ridge **142–144**
„ rise 112, **113, 114,** 134, **135**
„ run 112, **113, 114**
„ sarking 114, 148
„ setting out 115–138, 140–148
„ span 112, **113**
„ struts 145, 146
„ terms 112, **113, 114**
„ tile battens 114, 148
„ trussed 112, **113**
„ types **111–113**
Reinforced concrete (see concrete)
Reinforcing steel 225–227
Reproduction of drawings 42
Ridge **142–144**
Rim lock 205
Runners, ceiling **108, 109**

Sanding floors 169
Sashes **172–174**
Saw sharpening **24–26,** 27
Saws, use of **27, 28**
Sarking 114, 148
Scribers, fitting **194,** 195
Seasoning of timber 54, **55–58**
Semi-balloon construction 99, **101**
Scaffolding 212–217
„ acts and regulations 212
„ bearers 212, **213,** 214
„ brace 212, **213,** 214
„ brackets 213, **214**
„ fixings **213, 214**
„ guard rails 212, **213**
„ ladders **215**
„ members 212, **213**
„ planks 212, **213**
„ standards 212, **213,** 214
„ steel **214, 215**
„ timber **213, 214**
„ trestles 213, **214**
„ types 212
Screws **35, 36**
„ boring for 35
„ holding power 35
Sharpening tools **24–29,** 30
„ „ bits **30**
„ „ chisels 27, **28,** 29
„ „ plane irons 27, **28,** 29
„ „ scrapers 29
„ „ saws **24–26,** 27
Shortening definition 142
„ rafters (see rafters)
Shot-hole borer 60
Shrinkage of wood **53, 54**
Sill trays 175, **176**
Sink bench 197, **198**
Site survey **75**
Siting a house 41, **42,** 43
Sleeper plates **90,** 94
Slinging of timber **216,** 217
Socket bolts 207
Soffit linings 193, 194
Softwoods **46–49,** 72
Span, roof 112, **113**
Specifications 40
Spiral balances **205,** 206
Steel reinforcing 225–227
Steel square, use of 124–138
Steps concrete 222, **224, 225, 226**
Stringers **90**
Strutting, herringbone **97, 98**
Struts, roof 145, **146**
Stucco **162–164**
Studs **102, 103,** 107, **108**
Survey of site **75**

Termites **61–64**
„ prevention and control 63, 64
Tiles 140, 148
Timber 46–73
„ classification of 52
„ conversion of 49, **50, 51**
„ frame construction 99–109
„ grading 52
„ imported 73
„ indigenous trees, from 72
„ manufacture 49
„ measurement, **51,** 52
„ moisture in 52–54
„ native trees, from 72
„ scaffolding **213,** 214
„ scaffolding for, 212
„ seasoning 54, **55–58**
„ shrinkage **53, 54**
„ preservation 66–69
„ preventing fungal attack 65, 66
„ utilization 69–73
Timbering for excavations **216**

Tools, 11, **12–31–33**
„ care of 30
„ classification 11, 12
„ description and use **12–31**
„ power **30, 31**
„ „ safety precautions 32, 33
„ saw sharpening, for **24**
Tracings 42
Trades, attendance on other 209–211
Trees 46–73
„ classification of **46**
„ conversion 49, **50, 51**
„ exotic 73
„ felling of 49
„ growth of 46, **47**
„ hardwood **46–48,** 49, 72, 73
„ native 72
„ types of cells 47, **48,** 49
„ softwoods **46–48,** 49, 72
Trimmers (door, window, porch **103–105**
Trimmer studs 103
Truss roof 112, **113**
Two-toothed longhorn borer **60**

Utilisation of timbers 69–73

Valley rafters (see rafters)
Valley-jack rafters (see rafters)
Ventilation under floor space 85, **86**
Vertical boards and battens **156**

Walings 81, 82, **218, 219,** 220
Wall braces 104, **105, 106,** 109
Wall coverings, exterior 150–164
„ „ „ brick veneer 158, **159–162**
„ „ „ mineral fibre cement mouldings 158, **159**
„ „ „ „ „ „ sheets **157, 158**
„ „ „ „ „ „ sidings 156, **157**
„ „ „ stucco **162–164**
„ „ „ vertical boards and battens **156**
„ „ , interior 187–189
„ „ „ conditioning 188, 189
„ „ „ fibrous plaster sheets 187
„ „ „ plaster-core wallboard 187, 188
„ „ „ wallboards, fixing 189
„ „ „ „ , framing 189
„ „ „ wood fibre boards 188, 189
Wallboards 187–189
„ , fixing 189
„ , framing 189
Wall framing 99–109
„ „ assembly **103**
„ „ balloon-frame construction 99, **100**
„ „ braces 104, **105, 106, 109**
„ „ dwangs 107
„ „ erection 106, 107
„ „ jack studs 103, **105**
„ „ joints **101**
„ „ lintels **103–105**
„ „ platform construction 99, **100**
„ „ semi-balloon construction 99, **101**
„ „ studs **102, 103,** 107, **108**
„ „ timber grades **70,** 99
Wall plates **91, 93**
Wardrobes **197**
Water-cement ratio 232
Weatherboards 70, **150–156**
„ angle boxes 155, **194**
„ „ stops 155, **194**
„ bell-cast finish **156**
„ corner-mitred **155**
„ cover **150, 151**
„ exterior angles **153**
„ finishing against brick 195
„ „ „ concrete 195
„ interior angles **153,** 154
„ gable end 156
„ jointing **153,** 154
„ lap **150, 151**
„ nailing **152, 154**
„ quantities 170
„ spacing rods 150, **151**
„ soakers **155,** 156
„ straightening 154
„ tilting fillet **153,** 154
„ timber 70
Window 172–177
„ board 201, **202**
„ fittings **205,** 206
„ flashings **176, 177**
„ frames fitting 174–176
„ frames, fixing in brickwork **184,** 185
„ „ „ „ brick veneer 161, **162**
„ „ „ „ concrete **184,** 185
„ „ „ „ stucco **176, 177**
„ „ „ „ weatherboard **175, 176, 177**
„ sill tray 175, **176**
„ timber 71
Wood boring insects 58–64
Wood fibre boards 188, 189
„ preservation 66–69
Working drawings **38–40**

PRINTED BY WHITCOMBE AND TOMBS LTD., WELLINGTON, UNDER AUTHORITY,
A. R. SHEARER, GOVERNMENT PRINTER, WELLINGTON, NEW ZEALAND, 1969